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Possible global events and the stratigraphy of the Palaeozoic of the Barrandian (Cambrian–Middle Devonian, Czechoslovakia)

Události globálního významu a stratigrafie barrandienského paleozoika (kambrium–střední devon)

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Abstract: The Middle Cambrian up to Middle Devonian sequence of the Barrandian area in the central Bohemia shows the following turning points of event character in the stratigraphic development, as recognized by a thorough biostratigraphic and sedimentological investigation: 1. The Middle Cambrian transgression and regression, 2. The Tremadocian transgression, 3. The Llanvirnian transgression, 4. The suite of Mid-Ordovician (Llandeilian — Lower Caradocian) transgressive and regressive events, 5. The Lower Caradocian transgressive Event, 6. The Basal Kosov regressive Event, 7. The Ordovician-Silurian boundary transgressive Event, 8. The Upper Kopanina regressive Event, 9. The Basal Přídolian transgressive Event, 10. The Lochkovian-Pragian boundary regressive Event, 11. The Basal Zlíchovian Event, 12. The Daleje transgressive Event, 13. The Basal Choteč transgressive Event, and 14. The Kačák transgressive Event.
The transgressive events are mostly accompanied by the onset of anoxic conditions and new faunal elements.
The individual events are characterized according to their local or global character. The global character was recognized especially in the events given sub 1, 2, 3, 5, 7, 10, 12, 13, 14 which is explained by the eustatic sea-level changes. Local events, on the other hand, are caused by tectonic movements.

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Concept of the event stratigraphy

Modern stratigraphy tries to recognize and date the global events in the geological history. Their exact dating, reconstruction of their mechanism, and their correlation throughout the world might bring revolutionary ideas concerning the Earth's history.

The term "*event*" as well as the term "*event stratigraphy*" have been used in geology since the sixtieth. According to Webster's Dictionary (1951) the event is "... that which comes, arrives or happens, any incident especially a noteworthy one". Geological events belong to the geologic past — to the history of the Earth. They have been imprinted and fossilized in the structure of the Earth, in the sedimentary and magmatic envelope, or in the tectonic or biologic history of the Earth.

Stratigraphic event, moreover, has a direct relation to time, absolute or relative, with the relation to other events. The stratigraphic event was first defined by Hughes and Moody-Stuart (1969) as "an item or geologic information relatable (or potentially so) to the general evolutionary state of the Earth and based on a rock sample or on a general attribute (to include metamorphism) of some named rocks."

Up to now, two culminations of the event concept can be registered. The first one can be dated to the year 1980 when the idea about a giant global event — impact of a huge celestial body was accepted by a great part of the geological community. Probability calculations indicate that at least one large meteorite or comet with a mass of 10^{18} g or more and impact energy of more than 10^{25} J should have hit the Earth during the Phanerozoic (i.e. during the last 570 Ma). Alvarez et al. (1980) suggest that it happened at the end of the Cretaceous (65 Ma ago). This idea was based on the observations of drastic palaeontological and stratigraphic changes in the boundary beds and also on the iridium accumulation in the basal Tertiary sediments. This conclusion has been supported by Hsü (1980), Smit and Hertogen (1980), Emiliani (1980) and others. The idea of the fall of a great celestial body was applied also to some other stratigraphic boundaries, namely Permian-Triassic (e.g. Hsü 1980), Frasnian-Famennian (McLaren 1970, 1985, Alvarez et al. 1984, Playford et al. 1984), and Eocene-Oligocene (Pomerol 1984).

Second culmination of the event concept can be seen in the appearance of the book by Einsele and Seilacher "Cyclic and event stratification" (1982). These authors enlarged the event concept and recognized a wide spectrum of events in sediment sequences.

All the events mentioned above are really of global (world-wide) character and they manifest themselves by drastic palaeontological changes, by extinction of whole groups of animals, by changes in palaeogeography, and by sudden facies changes.

The falls of celestial bodies with all their consequences appear to be real events par excellence. They must have had an enormous and sudden effect on the whole Earth's surface. Namely, the heating and even vaporization of the ocean, formation of a giant tsunami wave, and devastation of a dry land surface are mentioned. There are, however, many other events which are classified according to their mechanism, duration and consequences. Pomerol's (1984) classification is widely accepted. He recognizes the following events:

1) Biological events — they comprise mainly the evolution, extinctions, onsets, migration, etc. and thus represent longer processes.

2) Magnetic events, i.e. inversions of magnetic field of the Earth.

3) Chemical events — mainly changes of the rate of stable isotopes ($^{18}O/^{16}O$, $^{13}C/^{12}C$); also marked variations in the amount of trace elements, like strontium, boron and manganese. The existence of chemical events enabled the development of a new branch of stratigraphy — so called chemostratigraphy (see Renard 1984).

4) Sedimentological events — they are of different type and duration. Some of them result from catastrophical processes (gravity currents), some of periodical slower changes of the environments (e.g. periodites).

5) Climatic events — they are of different duration and manifest themselves through the changes in water temperature, agitation, salinity, density and also through the changes in the amount of precipitation.

6) Volcanic events — they can be of a great significance, especially cataclysmatic eruptions with huge tephra production. They can be used in the stratigraphy mostly within the zones of collision and plate subduction.

7) Seismic events — numerous slides are produced by earthquakes; tsunamis are triggered by earthquake shocks. During tsunamis tsunamites and homogenites are deposited (see Kastens and Cita 1981) due to stirring and settling of deep water sediments.

8) Tectonic events — this wide spectrum of events starts with local deformations of the Earth's crust which leads to diachronic sedimentation and terminates with global changes in sea level triggered by the fluctuation in rates of sea-floor spreading. Large-scale oscillations in sea level (with the amplitude of more than 100 m) can be attributed to tectonic, less to climatic events. Many exceptions from this rule, however, are possible.

9) Cosmic events — impacts of celestial bodies of various diameter (see above).

Transgressive and regressive events (i.e. the rise and drop of the sea level) fall within different categories. They can be caused mainly by climatic and tectonic events, in some cases also by volcanic, seismic, and cosmic events.

The event classification given above shows that the nomenclature of events is based on various criteria, namely:

a) the process itself, e.g. impact, climatic changes, change in the rate of sea-floor spreading, reorganization of lithospheric plates, etc.;

b) the secondary effect of this process, e.g. transgression or regression, tsunami, turbidity current, warming or cooling of sea water, etc.;

c) the product of this secondary effect, e.g. black shale (anoxic, euxinic) event, phosphatic event, plateau basalt event, etc.;

d) stratigraphic setting. In this case the term event corresponds either to boundary beds (e.g. C/T — Cretaceous-Tertiary Event, E/O — Eocene-Oligocene Event) or to a stratigraphic unit of a different scale (e.g. Kellwasser Event, Llanvirn Event, etc.).

The denominations sub a and b are subjective to a great extent. The terms sub c and d, on the other hand, are purely objective and descriptive. That is why the priority should be given to them. In this paper the stratigraphically derived terms are used as well as in many recent papers concerning the event stratigraphy.

Table 1

The classification of events based mainly on the duration of the process (after Ch. Pomerol 1984, modified)

Duration	Process	Resulting effects
seconds	meteoritic impact, changes in current velocity	impact wave, formation of a single lamina
minutes	storms, turbidity and other gravity currents, tsunami	formation of a layer of tempestite, deposition of a layer of turbidite or tsunamite
hours	as above, processes of greater scale	as above
days	volcano eruption	deposition of tephra layer
weeks	floods	deposition of a layer of inundite
year	seasonal climatic changes	formation of varvite
10^2—10^3 years	global climatic changes	formation of pelagic laminite
10^3—10^5 years	unknown process possibly of solar character, changes in sea-floor spreading	formation of linear magnetic anomalies, oscillations of sea level with an amplitude of more than 100 m
10^5—10^6 years	global climatic cycles of a long duration	faunal extinctions and onsets, changes in sedimentation and facies

It can be observed from the classification of events given above that the term event attained a very broad sense. The events are of different duration; some of them are of catastrophic nature, the others indicate more or less gradual change in facies, fauna, deposits. Therefore, a recognition of events according to their duration is needed. This concept is summarized in tab. 1 (based mainly on Pomerol 1984).

From the viewpoint of the utilization of events in the stratigraphy, their period (recurrence interval) is of a great interest. Only such events having a recurrence interval longer than 1000 years might be of stratigraphic importance. The periods (recurrence intervals) of important events are given in tab. 2.

From the table 2 it follows that some events can be utilized for the stratigraphic correlation: global climatic oscillations, oscillations of sea level of great amplitude (more than several tens of meters), and possible impacts of celestial bodies. On the other hand, paroxysmal volcanic eruptions, turbidity, and other gravity currents and similar catastrophic events can be used within the limits of individual sedimentary basins and not in a global sense.

Table 2

Recurrence intervals (periods) of main events

Recurrence interval	Event
one year or less	deposition of a varve; hurricane and its deposits
10—100 years	extremely heavy storms, turbidity currents; 10 and 100 year floods; cataclysmatic volcanic eruptions,
10^2—10^4 years	climatic oscillations; giant turbidity currents
10^3—10^5 years	climatic oscillations; changes in a system of deep oceanic currents
10^5—10^7 years	magnetic inversions of the Earth's magnetic field; turning points in sea-floor spreading and reorganization of a movement of lithospheric plates; great changes in sea level stands
10^6—10^8 years	impact of great celestial bodies (with a diameter of more than 100 m)

Out of all events which are convenient for the stratigraphy, great oscillations in sea level stands are of the greatest interest. During last years there have been numerous attempts of global correlation of great transgressions and regressions. In 1977 well known Vail's curve was published (Vail et al. 1977). This curve is based on transgressions and regressions over a stable cratonic continental margin and is believed to represent real global changes in sea level stands. This rough graphical expression indicates several cycles in sea level fluctuation. Vail's curve has been generally accepted (e.g. Harland et al. 1982), partly criticized (e.g. Pomerol 1984); in all the cases it serves as a good working hypothesis for testing. In this paper, the transgressions and regressions in the Barrandian are compared with Vail's curve.

Some Lower Palaeozoic events have been already described from many regions: Ordovician and Silurian transgressive and regressive events (McKerrow 1979), Cambrian, Ordovician and Silurian events of different character (McKerrow 1979, Leggett et al. 1981), Early Ordovician transgressive and regressive events (Fortey 1984), Late Ordovician and Early Silurian events (Berry and Boucot 1983, and others), Devonian events (House 1983, 1985, Johnson et al. 1985).

Global versus local events in the Barrandian

Many Lower Palaeozoic sections in the United States, British Isles, Scandinavia, northern Africa, West Germany, South America were evaluated from the viewpoints of facies development, sediment succession and changes in faunal associations. The same approach is chosen in this paper. It is based on stratigraphical and palaeontological data compiled by I. Chlupáč and sedimentological data worked out by Z. Kukal.

The Barrandian Basin with its unusually well completely preserved sedimentary and faunal sequences of the Lower Palaeozoic, with good outcrops, deep structural and shallow boreholes, offers an excellent opportunity for testing a global importance of some events of different scale. The summary of an evaluation of the importance of Lower Palaeozoic events in the Barrandian is given in tab. 3.

During the long history of the investigation of the Barrandian Lower Palaeozoic main facies and faunal changes were explained by tectonic movements — namely rise and drowning of sills, vertical movements of basin floor and margins, as responses to main orogenic periods in the classic Stille's concept. Recent development of the concept of sudden faunal and depositional changes is directed to the events of wider, global scale, mainly the oscillations of the sea level. We hope that this paper will contribute to the solution of a crucial problem: global or local events?

It should be noticed that many changes of event character in the Barrandian, particularly some transgressions and regressions in the

Cambrian and Ordovician, were observed and described by previous authors, e.g. Kettner (1921, 1923), Havlíček and Šnajdr (1954, 1956), Bouček (1947), Röhlich (1956), Havlíček (1980, 1981, 1982). The event character of these important turning points in the sedimentary history, however, was not accentuated by them.

Method

In this paper the sedimentary and faunal sequences of the Barrandian were evaluated from the viewpoint of event stratigraphy. On Fig. 1 the stratigraphic succession is illustrated with indication of intervals and units which are discussed in detail. As said above, our attempt is to search for turning points in the Lower Palaeozoic history. These turning points can be characterized by:

a) angular unconformity, representing several Ma, pronounced change in the facies and fauna;

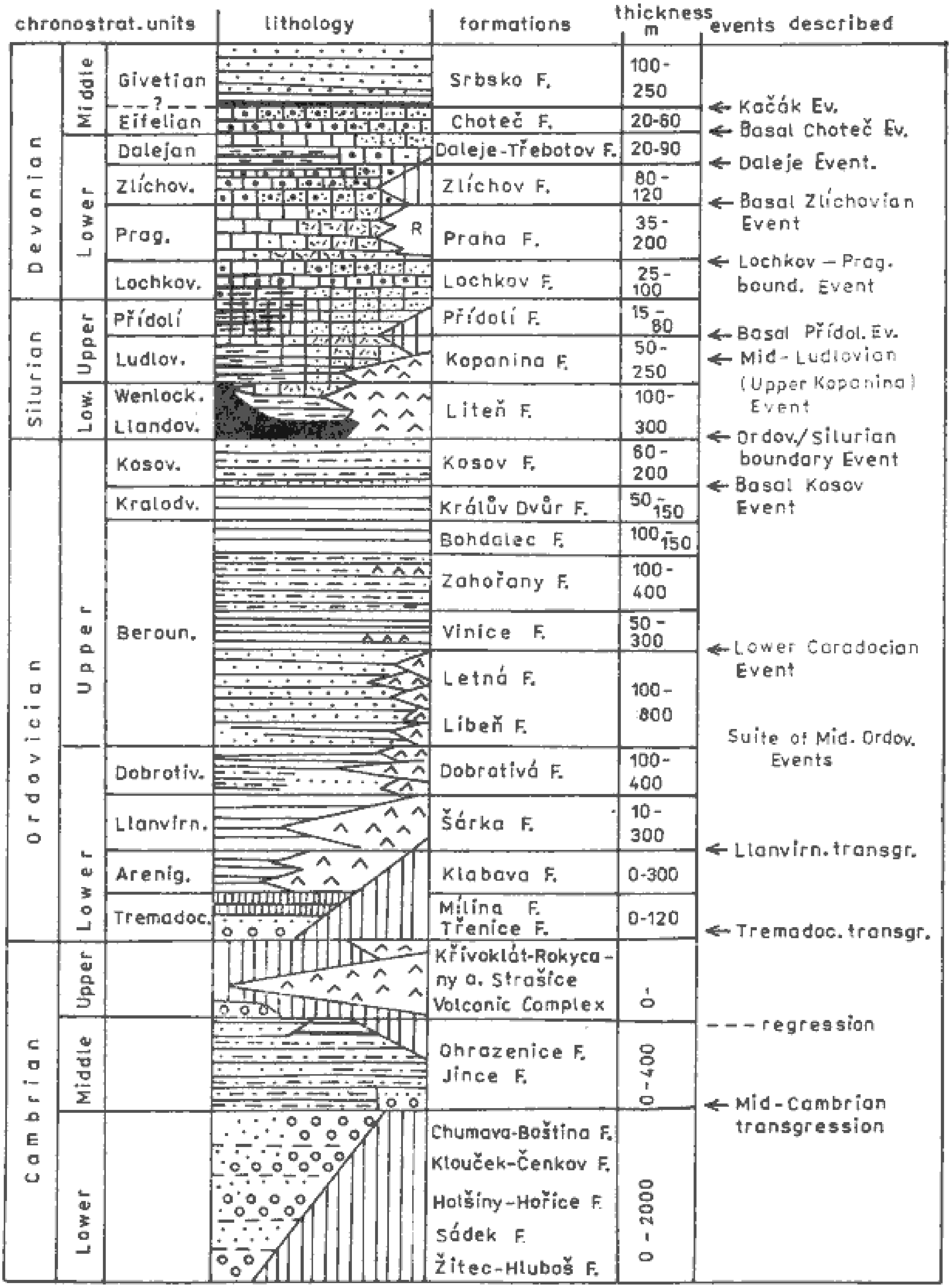
b) stratigraphic breaks, lasting one or several Ma. They can be accompanied by faunal changes and possibly also by a change in sedimentation;

c) drastic change in sedimentation (e.g. appearance of thicker conglomerate beds, change in limestone type), accompanied by faunal changes, appearance of black shales, red beds, etc.; the changes in sedimentation are of different scale. Cm-thick alternation of sandstones and siltstones corresponds to a period of several thousands of years, alternation of sandy and clayey units several tens of meters thick may correspond to periods lasting for several millions of years.

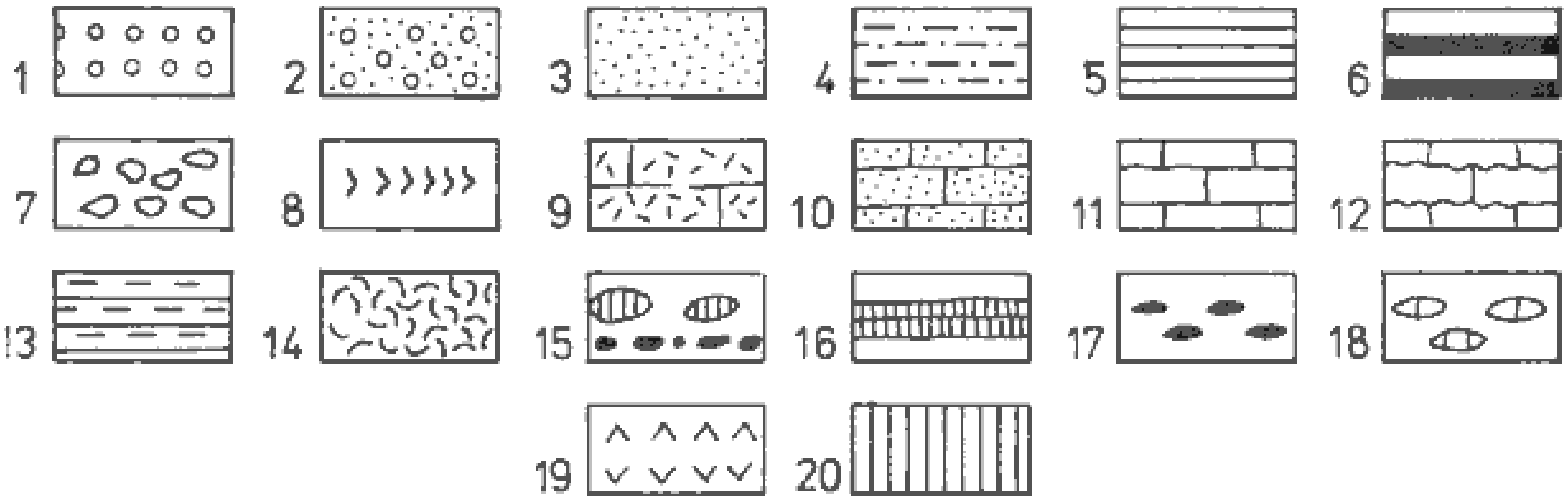
Most of the events could have been investigated in thoroughly studied sections. Some of them are illustrated. Graphic illustrations show lithologic succession, data on fauna, on some other important attributes (as black shale presence), sedimentary structures, etc.

The investigated event-bearing sections are described in the following order:

a) general information,
b) stratigraphic position and correlation,
c) sedimentary sequence with special attention to change in lithology and structures,
d) contents of fauna, data on extinctions, onsets of new forms and evolution,
e) the interpretation of depositional environment of sediments,
f) the discussion of events, their mechanism, duration, importance and possible global extent.



1. Stratigraphic scheme of the Paleozoic of the Barrandian area with position of events described



2. Key to lithologic symbols used in the presented paper
1 — coarse-grained conglomerates; *2* — fine-grained conglomerates; *3* — sandstones; *4* — siltstones; *5* — claystones; *6* — dark shales; *7* — sedimentary breccias; *8* — Fe-ores; *9* — coarse biodetrital limestones; *10* — fine biodetrital limestones; *11* — micritic and biomicritic limestones; *12* — micritic nodular limestones; *13* — calcareous mudstones; *14* — shell-beds; *15* — cherts; *16* — radiolarites; *17* — phosphorites; *18* — carbonate concretions; *19* — volcanic products; *20* — stratigraphic breaks

Chronostratigraphic units, such as the Tremadocian, Arenigian, Wenlockian, etc. are here treated as stages to be in accordance with the chronostratigraphic subdivision of the Devonian (see Chlupáč - Jaeger - Flügel 1981).

The Middle Cambrian transgression and regression

The early Middle Cambrian transgression is best documented in the Skryje area, in the NW flank of the Barrandian. The Mileč Conglomerate rests unconformably on the folded, uplifted and eroded Proterozoic rocks. The Mileč Conglomerate consists of a sequence of quartzose conglomerates and sandstones with mature clasts (quartz, quartzite, silicite) and slight admixture of unstable clasts (phyllites, porphyries). Both the conglomerates and sandstones are well sorted; sometimes they have pronounced bimodality reflecting the great intensity of shallow marine sorting processes. Fine grained layers contain a marine fauna with rather abundant articulate brachiopods *Pompeckium kuthani* (Pomp.), *Jamesella perpasta* (Pomp.) and *J. subquadrata* (Pomp.); other fauna is represented by trilobites *Ellipsocephalus vetustus* Pomp., *Perneraspis conifrons* (Pomp.) a.o., primitive gastropods *(Helcionella)*, rare edrioasteroids, etc. (comp. Jahn 1896, Pompeckj 1896, Růžička 1940 a.o.). Petrographic character, sedimentary structures, and fragmentary preservation of organic remains often concentrated in thin layers point to a very shallow environment, intertidal and very shallow subtidal environment (most likely Benthic Assemblage 2 in Boucot's, 1975 classification). The fauna of the Mileč Conglomerate was regarded by Pompeckj (1895) a.o. as Lower Cambrian, but rare finds of *Paradoxides* point rather to early Middle Cambrian age.

The Mileč Conglomerate is overlain by the well known Skryje Shales. On their base the local facies of the Týřovice Conglomerate is developed. Conglomerates and greywackes are interfingering with typical clayey shales thus representing only local development. The Týřovice Conglomerate can be easily distinguished from the underlying Mileč Conglomerate. The sediments of the Týřovice Conglomerate are of symmictite type (totally unsorted mixture of all the grain fractions). Great variability in the grain size can be observed from layer to layer. Conglomerates are of petromict nature. Unstable clasts prevail (Proterozoic phyllites, slates, spillites, porphyries) being accompanied by Proterozoic silicites (lydites) and a little of quartz clasts. Mud supported conglomerates pass often into the typical pebbly mudstones. Some quartzose sandstone pebbles were found which come from the underlying Mileč Conglomerate. Conglomerates are intimately associated with greywackes.

The mixtitic (symmictitic) character of the conglomerates led Walther (1888) to the view of their glacial origin. The presence of marine fossils, their sedimentary structures and total absence of any traces of pebble striation, however, speak in favour of deposition by means of mudflows in the deeper basin the bottom of which was beyond the reach of wave activity and stronger currents. The steeper palaeoslope can be proved by the presence of slump structures in pebbly mudstones and greywackes. In the conglomerates and greywackes abundant orthid brachiopods are present allied to that of the Mileč Conglomerate (*Pompeckium kuthani* is still present).

The proper Skryje Shale consists of nearly homogeneous sequence of clayey shales passing into silty shales and occasionally even into the siltstones. Some intercalations of fine greywackes are also present. All these sediments are structurally, mineralogically and chemically immature, which can be easily proved by the presence of unstable detritus and low values of Al_2O_3/Na_2O ratio. Carbonate is present as an admixture and in the form of concretions (siderite, ankerite, dolomite). This proper Skryje Shale, up to 200 m thick, contains a fairly rich trilobite-dominated fauna comprising more than 70 species so far known (trilobites — 35, hyolithids — 23, echinoderms — 7, brachiopods and less common representatives of some other groups). Trilobites are commonly preserved in complete exoskeletons, as in the case of the famous palaeontological localities in the environs of Skryje and Týřovice where also early growth stages of trilobites are locally common; also the preservation of other fauna points to autochthonism and deposition in quiet environment. A substantial part of trilobites lacks eyes (e.g. *Conocoryphe, Parabailiella, Ctenocephalus,* common agnostids) or shows somewhat reduced eyes *(Sao, Agraulos, Skrejaspis)*, but forms with well developed eyes are also frequent *(Eccaparadoxides, Hydrocephalus, Conokephalina, Solenopleurina, Ptychoparia)*. Although the basal greywacke may be ranged within the shallow subtidal zone of Boucot's Benthic Assemblage 2 or 3, the average fauna of the Skryje Shale points to a deeper subtidal zone of Benthic Assemblage 4 to 5 in Boucot's classification (1975). The basin depth can be estimated at several hundreds of meters.

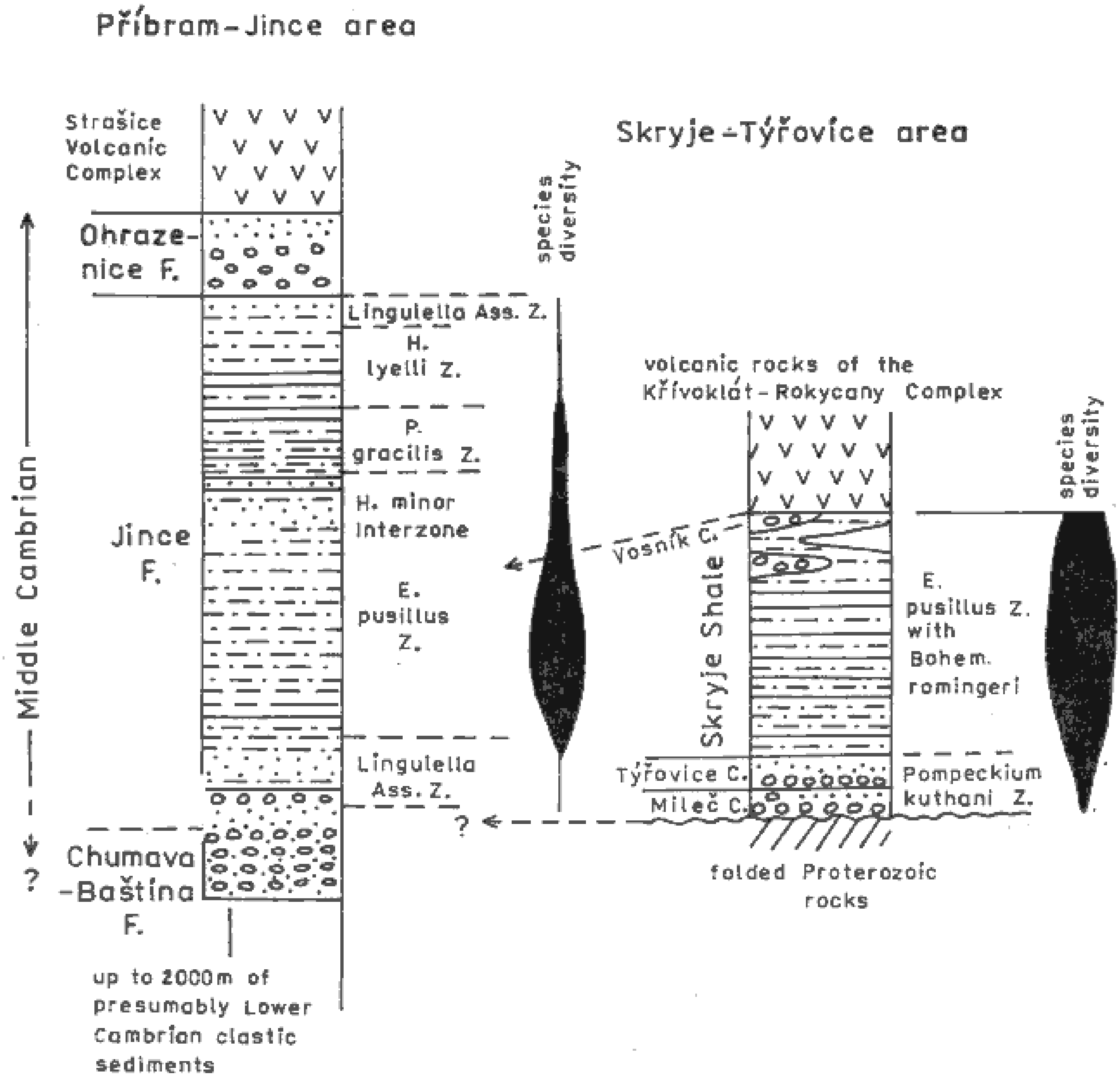
Biostratigraphically, the Skryje Shale belongs to the major Zone with *Eccaparadoxides pusillus,* i.e. to earlier part of the Middle Cambrian (Havlíček 1971, Sdzuy 1972).

In the upper part of the Sequence of the Skryje Shale the facies of the Vosník Conglomerate is locally present. The interfingering with fine-grained sediments of the proper Skryje Shale can be observed in many localities. By its grain size and sedimentary structures, the Vosník Conglomerate is very similar to the Týřovice Conglomerate described above. There are only slight changes in the clast composition. The Vosník Conglomerate is richer in spillite clasts. The depositional mechanism and environments of the two conglomerates could have been the same: deposition by mudflows and/or turbidity currents in a deeper basin. Perfectly developed slump structures speak in favour of steeper palaeoslopes.

The sedimentary sequence of the Skryje-Týřovice Cambrian is covered by the Cambrian volcanites of the Křivoklát-Rokycany Zone of the Upper Cambrian age.

There is no doubt about the sea level rise on the base of the Skryje Shale. The deepening of the basin floor made also the palaeoslope steeper and triggered gravity currents (mostly mudflows). The sharp boundary between the littoral and neritic Mileč Conglomerate and basinal Skryje Shale speaks in favour of sudden rise of sea level and deepening of the basin. Later, the sea level rise was succeeded by its drop which corresponds to the deposition of the lens-like Vosník Conglomerate. Even though this facies does not represent true shallow water deposits, it can be taken for the regressive member of the sequence. It is very probable that the real shallow water regressive deposits overlying originally the Vosník Conglomerate have not been preserved.

In the southern part of the Barrandian area (Příbram-Jince area, Brdy Mts.) there is a thick sequence of continental deposits composed mostly of the conglomerates and sandstones. They were deposited in the alluvial fans, braided and meandering rivers and ephemeral lakes. This thick sequence is ranged to the Lower Cambrian. The only megafossil — the arthropode *Kodymirus vagans* Chl. et Havl. found in a local layer of soft green Paseky Shale in the



3. Middle Cambrian correlations between the Příbram-Jince and Skryje-Týřovice areas (after V. Havlíček, 1971, supplemented)
F. — Formation, Z. — Zone, Ass. Z. — Assemblage Zone, H. — *Hydrocephalus*, P. — *Paradoxides*, E. — *Eccaparadoxides*, Bohem. — *Bohemiella*, C. — Conglomerate

Brdy Mts. — cannot prove the age with a sufficient certainity, but the great thickness of sediments (more than 2000 m) below the palaeontologically evidenced early Middle Cambrian points indirectly to the Lower Cambrian age (comp. Havlíček 1971, Kukal 1971).

The topmost part of this sequence — the Chumava-Baština Formation locally bears traces of deposition in a shallow basin (great lake or shallow sea). The sandstones and conglomerates are comparatively well sorted and some sedimentary structures as wedge-shaped cross bedding might indicate beach sedimentation.

Near above the boundary of the Chumava-Baština Formation and the overlying Jince Formation the pioneer *Lingulella* Community was found recently by Fatka and Kordule (in press) in sandstones and siltstones. This indicates the starting marine ingression.

The Jince Formation proper consists of truly marine deposits. Up to 450 m thick sequence is formed predominantly of siltstones with intercalations of fine-grained sandstones (greywackes and subgreywackes). Several layers of petromictic conglomerates are also present in the basal and upper parts of the sequence. Several layers of carbonates were also recognized, representing the first appearance of carbonate sedimentation in the Barrandian Palaeozoic. Thin layers of limestone with ubiquitous siliciclastic sandy admixture pass into sandstones with calcareous poikilitic cement. Concretions and disseminated carbonate consist of dolomite, siderite, and ankerite. Clayey sediments are of grayish-greenish colour having as much as 0.8 per cent of organic carbon. Illite and chlorite are the only clay minerals present. Great part of the sequence of the Jince Formation consists of a rapid alternation of finer and coarser sediments (e.g. siltstones/silty shales). The transitions between the beds are gradual and sometimes obliterated by bioturbation. Graded bedding occurs only exceptionally. Thus the bedding resembles far more the inundite than turbidite and its origin can be explained by fluctuations in the amount and grain size of the detritus brought into the basin. This bedding type is very close to that of prodeltal sediments, or basinal sediments with river influence. Lateral coarsening of the sediments westward and the existence of only younger zones in the western part of the basin led Havlíček (1971) to the idea of marine transgression coming from the east, although later the same author (1980, 1981) admitted also the possibility of a migration route to the NW.

The faunal diversity in the Jince Formation gradually increases from the lower parts upwards and decreases again in the upper parts of the sequence: the Lingulella Community passes in trilobite-dominated assemblages which allow to distinguish several local zones, namely the major *Eccaparadoxides pusillus* Zone (with *Acadolenus snajdri*, *Dawsonia bohemica* Subzones in lower part) and higher the *Paradoxides gracilis* and *Hydrocephalus lyelli* Zones in the upper part. The greatest faunal diversity is clearly shown in the *E. pusillus* Zone from which more than 40 species were described, including 25 taxa of trilobites, and 4 echinoderms. Richly represented benthos points to normal marine conditions. Commonly preserved complete exoskeletons, moult-stages and clusters of non-disarticulated specimens suggest — as in the Skryje Shale — autochthonism and rather quiet conditions in the deeper subtidal zone.

Ichnofossil assemblages are less diversified with predominance of planar to oblique *Planolites* and locally also *Chondrites* burrows, although short vertical burrows are also present.

During the higher parts of the Jince Formation, namely within the *Paradoxides gracilis* and *Hydrocephalus lyelli* Zones, gradual but very distinct decrease in faunal diversity took place. The progressive worsening of life conditions is still more marked within the *H. lyelli* Zone, where the diversity falls to 3 common species. Here, however, monotypic mass assemblages of *Ellipsocephalus hoffi* (Schloth.) with hundreds of complete exoskeletons crowded on some bedding planes are characteristic. In the upper part of the Zone monotypic assemblages of *Lingulella matthewi* Koliha occur (Šnajdr 1958, Havlíček 1971, Fatka in press).

The development of fauna in the Jince Formation thus reflects a closed cycle: the pioneer *Lingulella* Assemblage at the base passes gradually into high taxic diversity assemblage of the *Eccaparadoxides pusillus* Zone corresponding to normal marine conditions. The subsequent decreasing diversity in the *P. gracilis* and *H. lyelli* Zones reflects a gradual decline of marine regime and progressing isolation favourable for development of monotonous local assemblages terminating with *Lingulella matthewi* Community. The maximum depth of the marine basin can be estimated at several hundreds of meters. The shallowing of the basin in the upper part of the Jince Formation is demonstrated by the appearance of coarser sediments and by the onset of fluvial sedimentation of overlying quartzose conglomerates of the Ohrazenice Formation. These conglomerates fill the deep erosion channels cut into the underlying siltstones and greywackes of the Jince Formation (Kukal 1971).

The early Middle Cambrian transgression and subsequent late Middle Cambrian regression in the Barrandian fit well the general stratigraphic situation of the Cambrian in Europe and some other continents: Lower Cambrian shallow water clastics and carbonates are followed by deeper water basinal clayey deposits of "Paradoxides Shale" type (e.g. in Sweden, Wales, Shropshire, Armorican Massif, Morocco, Spain, Montagne Noire, Sardinia). The eustatic curves (Vail et al. 1977, Harland et al. 1982) show a great Middle Cambrian transgression and Upper Cambrian regression. The Middle Cambrian transgression caused anoxic conditions and black shales in the British Isles, Baltic Shield and eastern margin of the North American Craton and other regions are its result (Leggett et al. 1981). The Jince Formation and Skryje Shales in the Barrandian do not represent true black shales (their av. org. C content 0.28 %, max. 0.8 %), but there is some evidence of partly anoxic conditions in the basin during the maximum stand of sea level.

The Upper Cambrian regression caused the absence of the Upper Cambrian deposits in central Europe (except for n. Poland). Some recent finds of fossiliferous Upper Cambrian in s. Europe (Feist and Courtessole 1984), however, point to open migration possibilities within the mobile belts of Proto-Tethys along the northern Gondwana from southeastern Asia to southern Europe.

The Tremadocian transgression

During the Tremadocian a marine transgression took place in the Barrandian. Older relief consisting of Proterozoic sediments, volcanites and metamorphites, Cambrian sediments and volcanites, was covered with coarse siliciclastic deposits. The Barrandian Tremadocian is represented by two formations: the Třenice Formation and the Mílina Formation.

The Třenice Formation is composed mainly of petromictic conglomerates, coarse-grained and medium-grained sandstones (mostly lithic greywackes and lithic arkoses with some quartzose sandstones in the upper part of the sequence). The composition of sandstones and conglomerates reflects strongly the underlying lithology. Conglomerates and breccias overlying Proterozoic shales and phyllites are sometimes overloaded by shale and phyllite clasts and, on the other hand, conglomerates overlying Cambrian porphyries are rich in porphyry clasts. Grain size and sorting of the conglomerates is highly variable, as well as the roundness of their clasts. Totally unsorted breccias represent a reworked pre-Tremadocian regolith washed into the depressions during the transgression. Better sorted conglomerates and sandstones represent shallow marine deposits of sandy shorelines.

Faunal remains are generally sporadic in the Třenice Formation. They are distributed only locally, layers with common remains are exceptional. Fauna is less diversified, inarticulate brachiopods generally dominate. According to Havlíček (1982) benthic communities correspond to Benthic Assemblage 1 to 2 in Boucot's classification, i.e. tidal to shallow subtidal zone.

A lens of poor detrital sedimentary iron ore is bound to the base of the Třenice Formation near Holoubkov in the W part of the basin. It contains great amount of gravel- and sand-sized siliciclastic material. Hematite is the only ore mineral. It is supposed that the terrigenous supply from the weathered pre-Ordovician rocks might serve as a source of this ore. Special shallow-water life conditions are manifested by a local benthic assemblage in these hematitic ores at Holoubkov: common trilobites, articulate and inarticulate brachiopods and cystoids *Paleosphaeronites crateriformis* (Růžička) and *Glyptosphaerites*, best part of them unknown from other localities. Fragmentary preservation, local accumulations of organic remains show a high energy environment near the base of the Třenice Formation.

Ill-sorting of basal detritus, its relation to basement lithology and other factors indicate locally high relief of the pre-Tremadocian surface. Part of the basal Tremadocian sediments represents, in fact, slightly reworked regolith, formed mostly by physical weathering. The preservation of highly unstable detritus can be explained by rapid erosion and possibly also by cooler and semiarid climate. Periods of warm humid climate are, however, necessary to explain lateritic weathering enabling the deposition of a basal iron ore horizon.

The overlying Mílina Formation is characterized by the presence of silicites (cherts) of variegated colour, composed of microcrystalline quartz with some sponge spicules and variable amount of siliciclastic material of different grain size. Silicites often pass into sandstones with siliceous matrix (matrix supported sandstones and conglomerates). Lamination is totally absent but minor slump structures occur frequently. This lack of seasonal lamination together with the presence of huge amount of silica cement point to rapid deposition of gel-like masses of silica. Kukal (1963b) believes in the volcanic source of silica. Sponges could have thrived in waters oversaturated with silica and contributed to the deposition of cherts.

The fauna in the sediments of the Mílina Formation is less diversified; small inarticulate brachiopods strongly dominate. Trilobites in tuffaceous layers at Úvaly or in cherts at Olešná (Mergl 1984) are closely related to those of the Třenice Formation. Generally, the life conditions were very unfavourable throughout the deposition of the sediments of the Mílina Formation.

The correlation of the Třenice and Mílina Formations with the Tremadocian is proved particularly by means of brachiopod and trilobite fauna which contains some elements common mainly with the Leimitz Shale of Bavaria, Leetse Sandstone of the Baltic area, of Spain and the latest Tremadocian of the Holy Cross Mts. in Poland (comp. Havlíček and Vaněk 1966, Havlíček and Josopait 1972, Mergl 1984). The correlation indicates the presence of the Upper Tremadocian in the Barrandian. The only reported finds of *Dictyonema flabelliforme* (Eichw.) at Břežany e. of Prague (Kodym and Koliha 1926), which would point to the Lower Tremadocian, were not confirmed by a new palaeontologic revision caried out by J. Kraft (unpublished communication, 1985; specimens reported as *D. flabelliforme* belong to a separate species *Dictyonema intermedium* Prantl).

The Tremadocian transgression is documented from many areas belonging to different continental blocks, e.g. the two Iapetus margins (England, Wales, Poland, Scandinavia), cratonic North America, Gondwana margins (north Africa), Australia and NE Siberia (comp. Fortey 1984, Barnes 1984). The Tremadocian transgression in the Barrandian may represent a relatively short event of Tremadocian age. The Tremadocian transgression generally culminated in the higher Tremadocian and the Třenice Formation below the already regressive Mílina Formation of topmost Tremadocian age should represent a relatively short time interval.

It is well known that the area of deposition of the Mílina Formation was smaller than that of the Třenice Formation. This can be explained by local regression which was mentioned by several authors (Kettner 1921, Bouček 1947, Havlíček and Šnajdr 1956, Havlíček 1980). Global eustatic curves (Vail et al. 1977, Harland et al. 1982) show maximum sea level stand near the beginning of the Ordovician, as high as 400 m above the present sea level. This curve does not show any oscillations which could correspond to the regression characterizing the Mílina Formation. It can be therefore supposed that this regression in the Barrandian was caused by local conditions influenced by the tectonics.

The Llanvirnian transgression

The Šárka Formation of the Llanvirnian age can be subdivided into three major graptolite zones (Bouček 1975): the lower and the upper one allow a correlation with the lower and upper Llanvirnian of standard west European regions. Although some biostratigraphic problems near the Arenigian-Llanvirnian boundary still exist (supposed later, namely Llanvirnian, occurrences of some forms in the Barrandian which in western Europe appear already within the Upper Arenigian — see Bouček 1975, Thomas et al. 1984), the time of a marked Llanvirnian transgression falls in the Barrandian already in the Lower Llanvirnian.

Except for a thin layer of the basal conglomerate and breccia developed only on the transgressive base, the bulk of the Šárka Formation consists of clay sediments. Claystones and silty claystones strongly predominate. True black shales are present having more than 1.0 per cent of org. C. Layers of fine-grained quartzose sandstone and subgreywacke occur sporadically. Carbonate admixture is frequent in the form of disseminated aggregates (calcite, dolomite) as well as in concretions (very often silicified). Basal breccias and greywackes contain great portions of unstable detritus. A majority of the sediments of the Šárka Formation, however, is rather mature. The claystones display high values of Al_2O_3/Na_2O ratio (more than 20) and coarser admixtures consist mostly of quartz.

In this shale development, the macrofossils are less common and represented by dominant pelagic elements, namely phyllocarid crustaceans (*Caryocaris*, possibly epiplanktonic), graptolites (*Didymograptus, Corymbograptus, Expansograptus, Pseudoclimacograptus*, etc.) and rather rare remains of other groups (trilobites, brachiopods, etc., also supposed land-plant *Bojophyton pragense* Obrhel found at Prague). Phytoplankton (acritarchs) is common. Ichnofossils are common but less diversified, represented by monotonous *Planolites* and *Chondrites* dominated assemblages. This association can be possibly ranged within a deeper subtidal life zone (Benthic Assemblage 5—6 in Boucot's classification).

At many places in western part of the Barrandian (environs of Rokycany and Mýto), at Prague, and in the eastern part of the basin (Úvaly, Brandýs n. Labem) the claystones contain numerous siliceous (originally carbonate) concretions. They yielded common, prevalently benthic macrofauna of great diversity: trilobites (about 60 species known), orthid brachiopods, carpoids and other echinoderms, gastropods, hyolithids, nautiloids, bivalves, ostracods, etc. (see the list e.g. in Havlíček and Vaněk 1966). Pelagic elements are also present (graptolites — particularly *Didymograptus*, the phyllocarid *Caryocaris*, etc.); acritarchs and chitinozoans are prolific. The whole macrofossil assemblage contains about 170 species so far described; microfossils are known incompletely. Organic remains preserved and often accumulated in concretions are usually well preserved showing no marked traces of transport: trilobites rather frequently in complete exoskeletons, carpoids not disarticulated, articulated shells of brachiopods. Trilobites with well developed eyes predominate, although some forms with reduced eyes are present [*Ectillaenus, Trinucleoides,* some dalmanitids] and bathypelagic cyclopygids are rather common (*Cyclopyge* a.o.). Havlíček [1982] called the assemblage according to the characteristic brachiopod genus "The Euorthisina Community" and ranged it within the Benthic Assemblage 3 and possibly deeper in Boucot's [1975] classification. The depth can be estimated at several tens of meters, while the depth of the deposition of "normal" black shales at several hundreds of meters.

Minor depths characterized the marginal parts of the basin, where basal breccias, conglomerates, and sandstones are developed. In a great part of the basin volcanic center evolved consisting of huge accumulations of volcanites and volcaniclastic rocks. The volcanic material was spread far from the volcanic center and formed layers of tuffs, tuffites and tuffitic shales.

Lenses of sedimentary iron ores, partly oolitic, are bound to the Šárka Formation. They are limited mostly to marginal parts of the basin. They are mainly hematitic, but pass often basinwards into chamositic and sideritic types. They contain only small fragments of brachiopods — this indicates that the life conditions were very unfavourable. Shale intercalations and intimately overlying shales yielded at several places graptolite fauna — evidently transported and deposited by currents (e.g. Mníšek, Krušná hora). Trace fossils of *Bergaueria* and *Planolites* types are present in shale and siltstone layers within and near the ores.

Long discussion about the source of iron and depositional environment of the sedimentary iron ores led to the idea of terrigenous source of iron, even though weathered volcanites and tuffs might have served also as an important source. Iron ores deposited in extremely shallow water in high-energy environment, mostly in partly sheltered parts of the basin (the barriers were formed by sills, horsts, and volcanic accumulations). The conditions in these sheltered marginal parts of the basin differed from those in the main basin, mostly in lower salinity and greater concentration of iron and heavy metals in water. All the sediments associated with iron ores possess higher amounts of iron, manganese, and heavy metals than these in the main central parts of the basin (Kukal 1963).

In general, the fauna of the Bohemian Llanvirnian (Šárka Formation) markedly differs from that of the Arenigian (underlying Klabava Formation) not only in much greater diversity, but particularly in an influx of new elements; majority of genera of trilobites and other benthic organisms occur here for the first time, e.g. trilobite genera *Selenopeltis, Leiagnostus, Pricyclopyge, Degamella, Symphysops, Ectillaenus, Uralichas, Colpocoryphe, Pharostoma, Bohemilla, Bathycheilus, Placoparia, Areia, Trinucleoides, Eoharpes* a.o. and the same holds for echinoderms, brachiopods, hyolithids, gastropods, bivalves, nautiloids a.o. Among graptolites, the common occurrence of *Didymograptus* and *Corymbograptus* is most characteristic. The general influx of new elements points to a transgression which allowed the invasion of new benthic and pelagic fauna.

The greater part of sediments of the Šárka Formation belongs to the anoxic (euxinic) facies which is clearly bound to great transgression (see Leggett et al. 1981). Eustatic curves (Vail et al. 1977) do not show marked transgression in Llanvirnian times because they mostly indicate the undifferentiated rise of sea level from the basal Ordovician to the Mid-Ordovician, but the evidence from many regions shows that the Llanvirnian transgressive and mostly anoxic event was really of world-wide character. Data on the Llanvirnian transgression are known from many areas of Europe (apart from the Barrandian, particularly from S. Wales, France, Spain, Sweden) where the onset of graptolitic shales and invasion of *Didymograptus* (*Didymograptus*) are well traceable. A similar picture is reported from north Africa, Saudi Arabia, platform North America, and Australia (data summarized in Fortey 1984). General character of the Llanvirnian facies and faunas from Bohemia fits thus well the worldwide Llanvirnian trend and pattern.

Suite of the Mid-Ordovician events

The Llandeilian and a part of the Caradocian sequence (Dobrotivá and Libeň Fms.), can be subdivided into units with predominantly sandy character and units with clayey nature. The thickness of individual units varies from 30 to 120 m. Each boundary between sandy and clayey unit can be classified according to the event stratigraphy as a minor event (or event of the second or third order).

Moreover, sandy units can be subdivided into a number of sandstone strata alternating with strata composed of finer sediments. Stratum thickness varies from several tens of centimeters to several meters. Each stratum boundary can be taken for a small-scale event.

Sandstones of sandy units are represented by supermature quartzose sandstones, fine- and medium-grained with occasional intercalations of fine-grained conglomerates. Rounded clasts prevail being cemented with silica cement. The silica content of the sandstones is as high as 99 per cent. They possess only ultrastable association of heavy minerals. Sandstones are usually without body fossils, but organic life is documented by very common ichnofossils: vertical burrows of *Skolithos* (= *Tigillites*) and *Monocraterion* types strongly dominate representing the characteristic *Skolithos* Ichnofacies. Some dark grey siltstone and subgreywacke layers embedded in sandstone sequences contain somewhat different ichnofossil assemblage dominated by intrastratal *Planolites* burrows; vertical burrows of *Monocraterion* type are also common, but not prevailing. Traces oblique to bedding and horizontal traces predominate, they correspond to a less diversified *Cruziana* ichnofacies. Body fossils were found in the sandstones only at several localities, where they are represented by fragmented and sorted remains of disarticulated trilobites, orthid brachiopods, echinoderms, conulariids, etc. (Havlíček and Vaněk 1966). In thicker sandstone (quartzite) layers, they are associated with mud and siltstone pebbles (e.g. in the Řevnice Quartzite in the environs of Rokycany and Zbiroh towns in western part of the basin).

The clayey units and claystone intercalations in sandy units are mostly pure claystones passing into silty and sandy claystones. Because of their dark colour and higher content of org. C (av. 0.4 per cent, max. 1.1 per cent) they can be taken for black shales. The biofacies of the shales of the Dobrotivá Formation is similar to that of the Šárka Formation (see above): shales are usually very poor in macrofossils (*Caryocaris,* inarticulate brachiopods, graptolites, etc.). Markedly richer fauna is concentrated in carbonate concretions at some paleontological localities in the vicinity of Prague and in western part of the basin: rather common trilobites (about 50 species described), hyolithids, gastropods, bivalves, conulariids, less common echinoderms, brachiopods, nautiloids, etc. accompanied by pelagic elements (*Caryocaris,* graptolites, acritarchs, chitinozoans). According to Havlíček (1982), the claystone facies of the Dobrotivá Formation contains the *Paterula circina* Community which belongs to a rather deep water life zone of Boucot's Benthic Assemblage 6, although the paleontologically richer layers may indicate some shallower environment. Shales of the Libeň Formation are almost devoid of macrofossils and only sporadic finds of brachiopods, trilobites, and phyllocarids are known. They correspond again to the deep water Paterula Community according to Havlíček (1982).

On the boundary between sandy and clayey units some small lenses of sideritic, silicate and haematitic iron ores occur. A lens near Kařízek, which overlies volcanites and underlies shales, yielded well preserved large conulariids *Metaconularia imperialis imperialis* (Barr.); other fauna, which is rare, is analogous to shale facies of the Dobrotivá Formation.

From the sedimentological and palaeoecological viewpoints, it can be summarized that quartzose sandstones (quartzites) are a product of shallow water environment called "prograding sandy shoreline" (i.e. sand bars and barriers, sand flats, neritic bottom above wave base). Clayey sediments were deposited below wave base, mostly in anoxic conditions. Sandstone layers markedly split and pinch out basinwards. The basin depth increased from its margins to the center from zero to several hundreds of meters.

Minor events — alternation of sandy and clayey units was previously explained mainly in terms of the uplift and subsidence of the rises bordering the basin. Their uplift resulted in the onset of sandy sedimentation and vice versa. According to present views the beginning of the deposition of black shales might indicate sea level rise and deepening of the basin. Anoxic conditions invaded the water column synchronously with the sea level rise. On the other hand, the shallowing of the basin led to the spreading of sandy material over the greater part of the basin floor.

The alternation of sandy and clayey layers within the sandy units was caused by small scale events. The boundaries between the beds are sometimes sharp, sometimes gradual, often bioturbated. Wash-outs are numerous, graded bedding almost absent. Turbidity sole marks are lacking. Thus the turbidity current mechanism of deposition of sandy layers can be excluded. On the other hand, wedge-shaped and also hummocky cross bedding associated with heavy mineral concentrates speaks in favour of intensive wave activity and reworking. Storm effects in the deposition of sandy layers are very probable. Heavy storms spread sandy material into greater depths of water and deposited real tempestites. Single storms could deposit only thin strata, several centimeters or tens of centimeters thick. For thicker quartzite beds we must suppose either amalgamation and deposition of several successive heavy storms, or temporary shallowing of the basin which caused the lateral shift of sandy facies basinwards. This depositional mechanism was typical of the Skalka and Řevnice Quartzites.

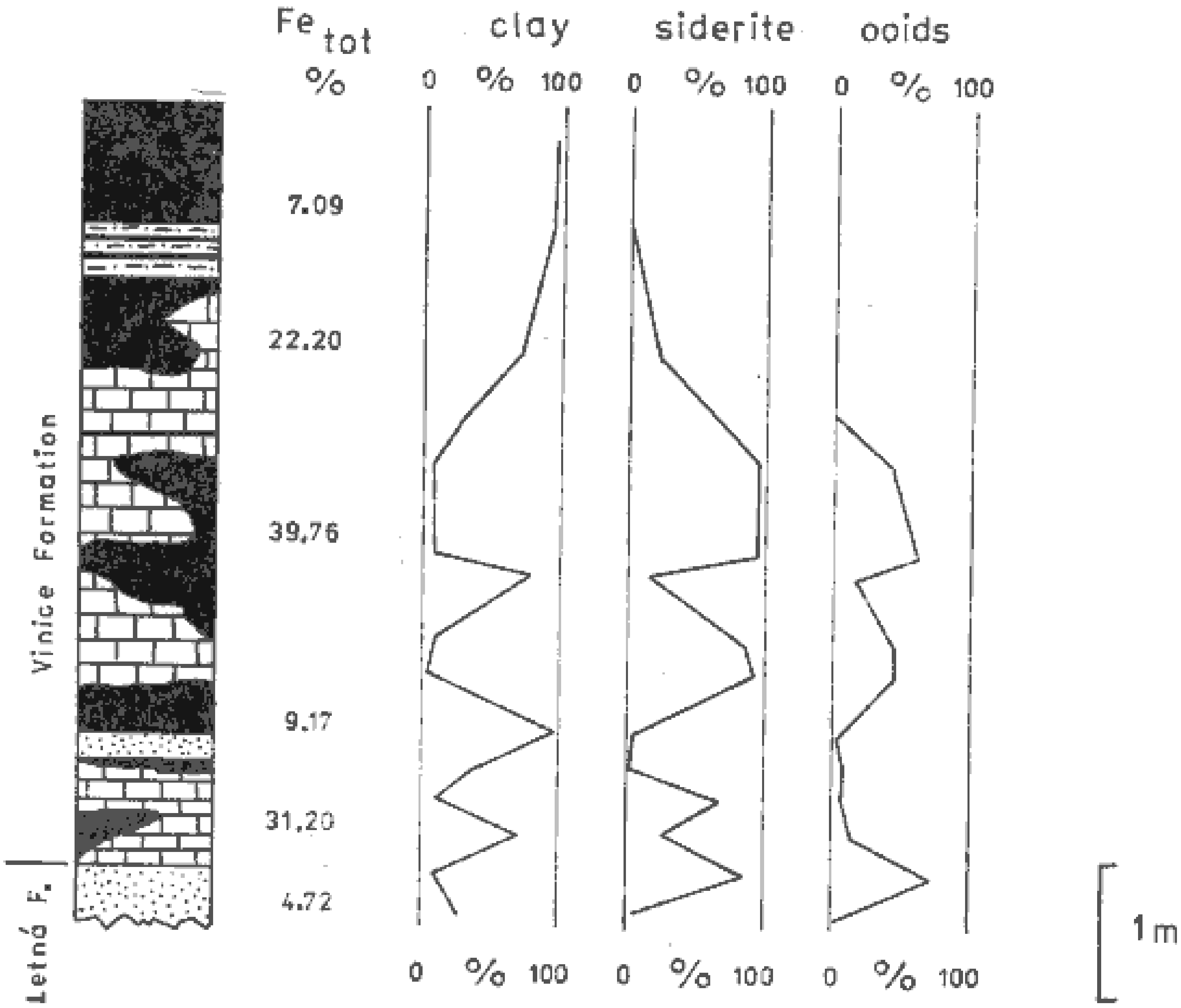
Two sandy units, Skalka and Řevnice Quartzites, indicate two sea level drops of about several tens of meters. First regression occurred in the Lower Llandeilian (Dobrotivian), the second higher within the Llandeilian. These regressive phases did not cause pronounced changes in the configuration of the basin and breaks in sedimentation. Lower Llandeilian regression has some analogies in other areas (England, Saudi Arabia, SE China, a.o., comp. Fortey 1984). The deepening of the basin expressed in the shale facies of the Libeň Formation may precede the beginning of the worldwide Caradocian transgression. Unfavourable life conditions in the sea and the lack of fossils, hinder to make any exact conclusions on the onset of the Caradocian transgression in the Barrandian according to the standard graptolite zonal scheme.

The Lower Caradocian Event

The Lower Caradocian Event is placed to the boundary between the Letná Formation and the overlying Vinice Formation. This boundary is similar to those between underlying set of sandy and clayey units, but is more pronounced and marked with well developed lens-like horizon of sedimentary iron ores (Zdice-Nučice "Horizon", see fig. 4).

The Letná Formation is developed mostly as a manyfold alternation of coarser and finer sediments (bed thickness usually from several centimeters to several tens of centimeters). Coarser layers consist of fine-grained sandstones (subgreywackes), often with dolomitic and calcitic cement. Finer beds are formed of sandy siltstones, clayey siltstones, and clayey sandstones. All the sediments are strongly bioturbated. Graded bedding is mostly absent. Sediments are mineralogically and chemically mature.

The sediments of the Letná Formation are generally poor in fossils except for ubiquitous trace fossils. Palaeontologically rich layers are concentrated in the upper part of the Formation in the NW limb of the basin in the neighbourhood of the town of Beroun (classic localities as Děd, Trubská, Veselá, etc.). Here, organic remains show traces of local transport (they are mostly fragmentary, concentrated in thin layers and lenses, sorted according to their size). Trilobites *Dalmanitina socialis* (Barr.) and locally also *Deanaspis goldfussi* (Barr.) dominate being accompanied by less common brachiopods (particularly orthacean), conulariids and other subordinate groups, namely crinoids, carpoids, cystoids, bivalves, gastropods, benthic ostracods, nautiloids, rare merostomes and others non-trilobite arthropods (fauna discussed by Chlupáč 1965, Havlíček and Vaněk 1966, Havlíček 1982). According to Havlíček (1982), this association corresponds to shallow subtidal zone; Benthic Assemblages 3 to 4 in Boucot's (1975) classification. More than 100 species are described from the Letná Formation. Trace fossils are abundant and diversified — in general the association corresponds to the *Cruziana Ichnofacies* in Seilacher's sense: common epi- and intrastratal burrows, irregularly inclined, horizontal and vertical traces of *Domichnia, Fodichnia* and *Pascichnia* (common *Skolithos* and *Monocraterion, Diplocraterion, Arenicolites, Planolites, Palaeophycus*), but also epistratal *Gordia, Didymaulichnus, Bifungites* a.o.



4. Examples of sequences reflecting the Lower Caradocian Event Petrographical changes within the Letná and Vinice Formations boundary beds, showing the variation in the grain-size and contents of carbonate, clay and ooids. Chrustenice ore mine, sw. of Prague

Some facial changes can be observed in the Letná Formation. In the marginal parts of the basin the deposition in the littoral zone is evidenced by the presence of mud cracks, rill marks, wrinkle marks, etc. The bulk of the sequence can be interpreted as inundites deposited within the reach of the input of river-borne material. Flood stages alternated with low water stages which caused the alternation of coarser and finer sediments.

The overlying Vinice Formation is represented by a sequence of claystones with black colour (i.e. typical black shales, with the average org. C content 0.68 per cent, max. 1.2 per cent). Coarser admixtures, fine sand and silt, are common. Carbonate concretions of various size are scattered throughout the shales (carbonate is represented by siderite and ankerite). Many shale layers contain greater admixtures of disseminated calcite aggregates. The fauna of black shales of the Vinice Formation contrasts with its uniformity with that of the Letná Formation. It consists of minute brachiopods [common *Paterula bohemica* Barr., *Aegiromena aquila aquila* (Barr.)], small infaunal bivalves, rather common trilobites *Deanaspis senftenbergi* (H. and C.), *Dalmanitina proeva* (Emmr.), *Selenopeltis inermis beyrichi* H. and C., ostracods, hyolithids, less common graptolites, etc. According to Havlíček (1982), this fauna belongs most likely to rather deep water Benthic Assemblage 6 in Boucot's (1975) classification.

Anoxic conditions governed in the whole basin during the deposition of black shales of the Vinice Formation. Slight temporal aeration enabled the inhabitation of the bottom by benthic fauna and deposition of carbonate. Sea level was higher than during the sedimentation of the Letná Formation and the maximum basin depth could be estimated at several hundreds of meters.

The boundary between the sandy Letná Formation and the clayey Vinice Formation is followed by lens-like horizon of sedimentary iron ores. Ores are oolitic with chamositic and sideritic ooids (sometimes also hematitic and even magnetitic) and mostly sideritic groundmass. Sandy, silty, and clayey admixtures are common as well as phosphate (of apatite structure). The fauna is very rare in the ore, but lens-like layers yielded some special forms, e.g. cystoid *Orocystites helmhackeri* (Barr.), *Hippocystites batheri* Chauvel, trilobites *Cekovia goetzi* Šnajdr, *Marrolithus ornatus paulisper* Přib. et Van., *Selenopeltis inermis cap* Šnajdr. etc., gastropod *Platyostoma ferrigenum* Per., etc. Also accumulations of cystoids, parallelly arranged shells of orthocone nautiloids and some other fossils were observed. Benthic forms strongly prevail. The relationship to the fauna of the underlying Letná Formation and the mode of occurrence point to the subtidal zone, Benthic Assemblage 3 to 4 in Boucot's (1975) classification (Havlíček 1982). Some unusual life conditions are documented by character of the fauna.

The deposition of iron ores took place in the time interval when the basin stopped to be supplied with terrigenous siliciclastic material. Thus chemogenic sedimentation was accentuated, especially in the marginal parts of the basin with shallow-water and sheltered environment. The former idea of the volcanic source of iron is being abandoned nowadays and terrigenous source is proclaimed (see Kukal 1963b).

The eustatic curves (Vail et al. 1977, Harland et al. 1982) show high sea level stand during the Caradocian. Detailed analysis of Ordovician sea level changes (McKerrow 1979) shows a regression within the Caradocian followed by a transgression in the Late Caradocian (Marsbrookian to Onnian). This is known from Wales (Llandovery, Llandeilo areas), Shropshire. Progressive deepening during the Caradocian was found in Shropshire and similar pattern in north Africa (McKerrow 1979). Fortey (1984) indicates by his eustatic curve the highest stand of sea level during the Caradocian, even higher than during the Llanvirnian transgression. His curve does not show intra-Caradocian oscillations.

From the above-said it follows that the situation in the Barrandian corresponds to the main trend of the sea level changes during the Caradocian, namely to the marked Caradocian transgression. Large-scale events, however, were combined with local tectonic movements, and the transgressive event at the Letná-Vinice Formations boundary may indicate the beginning of somewhat delayed Caradocian transgression.

The Basal Kosov Event

A very distinct event manifests itself on the boundary between the Králův Dvůr and Kosov Formations. This boundary corresponds to that between the Kralodvorian and Kosovian regional stages and falls within the Ashgillian (see fig. 5).

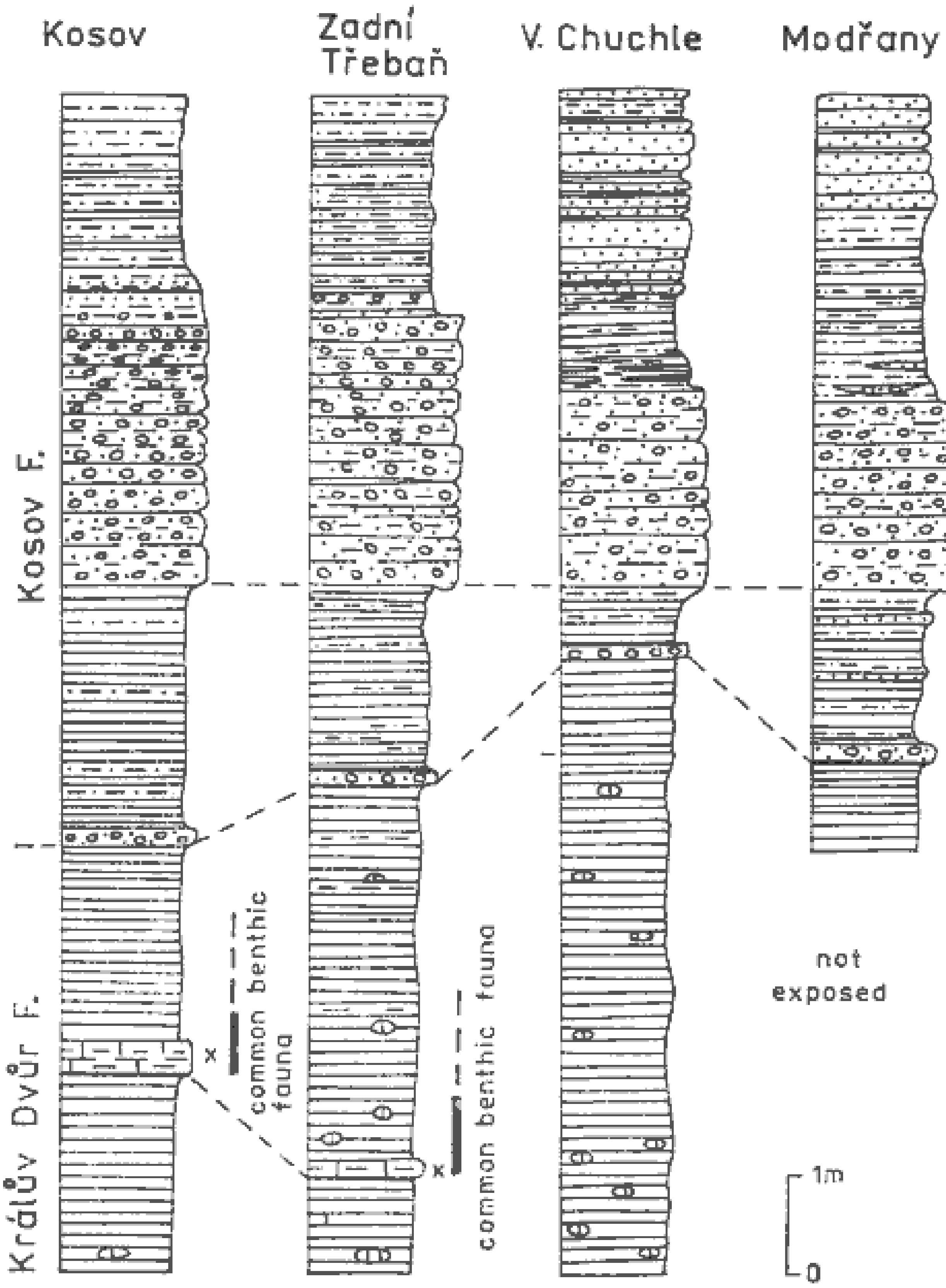
The Králův Dvůr Formation consists of pure claystones of greyish and grey-green colour. The amounts of coarser silty and sandy admixtures are generally small. Org. carbon content is generally low (below 0.15 per cent). The amount of carbonate and pyrite concretions rises locally. Pyrite seems to be of diagenetic origin. Pronounced changes can be observed in the topmost parts of the succession: The amount of sand admixture and calcite increases. Individual bed of silty marlstone (30—40 per cent $CaCO_3$) develops; little higher also a thin, laterally persistent bed of coarse-grained gravelly sandstone appears. At the base of this bed the boundary between the Králův Dvůr and Kosov Formations is usually drawn.

The fauna is not very common in the Králův Dvůr Formation, but its diversity is fairly great (more than 180 species described). Benthic organisms are richly represented (trilobites, brachiopods, bivalves, gastropods, ostracods, echinoderms); they are associated with nektonic and planktonic ones (nautiloids, graptolites, etc.). Clear faunal relationships to other European and even particularly northern areas (Poland, Kielan 1959, Tretaspis Shale of Scandinavia) may reflect warmer climatic influences. The topmost assemblage of the Králův Dvůr Formation is markedly different from the preceding one and is characterized by common trilobites *Mucronaspis grandis* (Barr.), *Stenopareia oblita* (Barr.), *Duftonia morrisiana* (Barr.), graptolite *Glyptograptus teres* (Perner), etc. (more than 50 species are known). This assemblage is bound to a single carbonate layer 10—30 cm thick (see above) and to overlying grey-green shales (Chlupáč 1951, Marek 1952). Upwards, this assemblage rapidly disappears and a few meters higher a thin (usually 15 cm) layer of coarse-grained sandstone with mud and shale balls and fragments represents another persistent bed which can be found in all the sections studied. It is overlain by 1 to 3 m thick silty shale with rare fossils only.

The homogeneity of the clayey deposits of the Králův Dvůr Formation and low organic matter content indicate a deposition far below the wave base in the basinal, several hundreds of meters deep environment. Water masses were slightly aerated. The described changes in the topmost parts of the sequence, especially the increase of sand admixture and the appearance of micritic carbonate with benthic fossils indicate a pronounced shallowing of the basin.

The proper base of the Kosov Formation is made of coarse-grained and medium-grained sandstones. Cut-and-fill erosional structures can be observed on the base of this sandstone. This quartzose sandstone is well sorted, sometimes bimodal (coarser mode 0.5—1.0 mm, finer mode 0.05—0.1 mm) and passes even into the fine-grained conglomerate. In both sandstones and conglomerates clayey matrix is present and patch-like distribution of poikilitic calcite cement can be also observed. This basal Kosov sandstone represents undoubtedly extremely shallow water environment and there is even suspicion of continental fluvial deposition.

Above the basal sandstone layer there is a succession of alternating fine-grained sandstones, siltstones, and mudstones. The sandstones belong to the class of quartzose sandstones which are supermature with calcitic cement (often poikilitic). This sequence somehow resembles flysch deposits in a rapid alternation of coarser and finer deposits and that is why it is often called "flyschoid sequence". It differs, however, from a true flysch by the absence of graded bedding and lens-like development of coarser strata. Body fossils are almost absent which



5. Examples of sequences showing the Basal Kosov Event Kosov hill near Beroun (quarry on the NW slope), Zadní Třebaň (railway cut), Velká Chuchle (slope on the left bank of the Vltava river), Praha - Modřany (highway cut at Tyršova čtvrť). *x* — carbonate layer with common benthic fauna

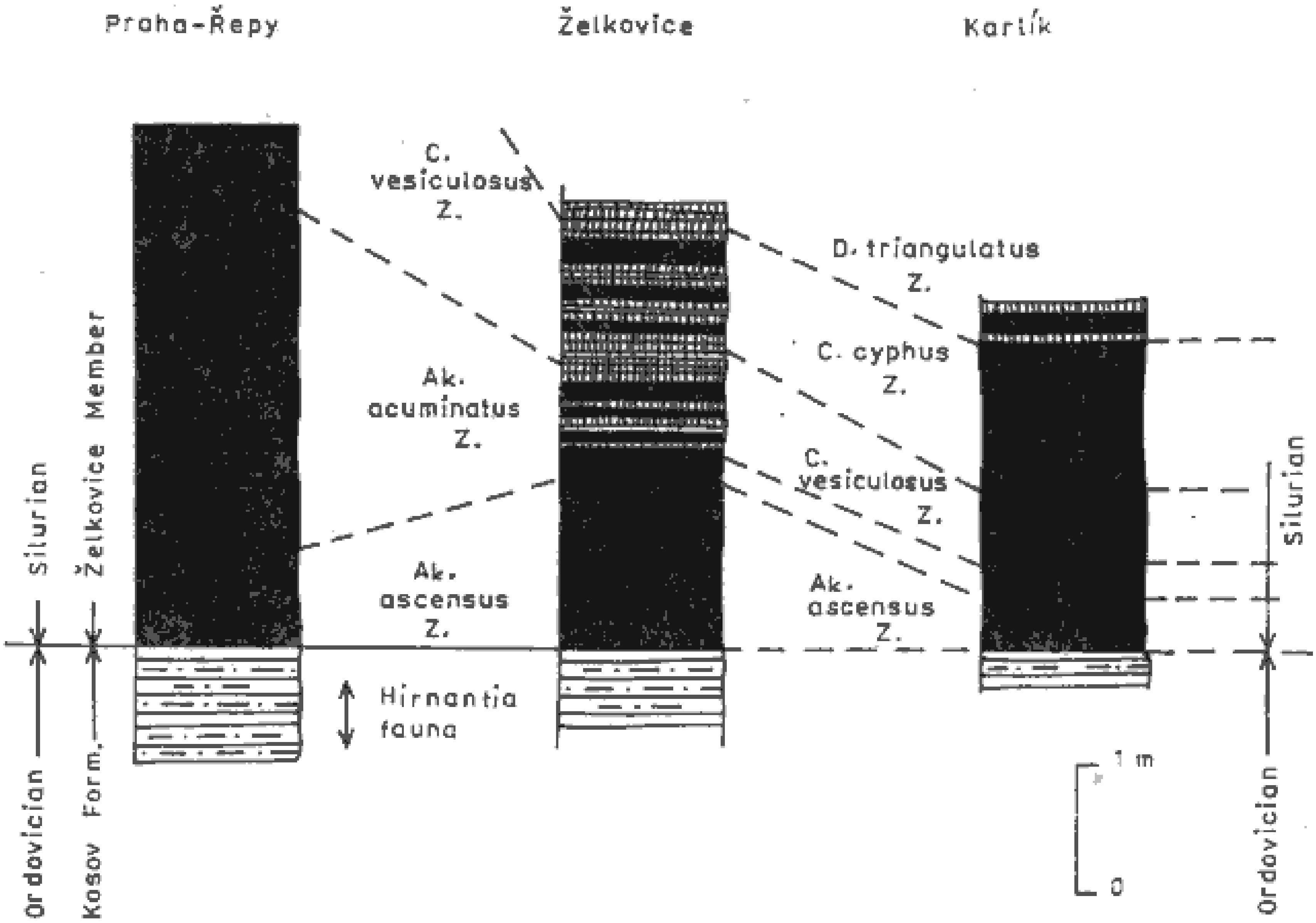
can be explained by the dissolution of calcareous shells and redistribution of the calcite into the cement. There were some doubts concerning the depositional environment of these sediments. Bouček and Přibyl (1958) according to the occurrences of some flysch sole marks compared them to turbidites settled down in a deeper basin. There are, however, many evidences speaking in favour of a deposition in shallower sea, even with temporary emerging bottom: mud cracks, wrinkle marks, herringbone cross stratification, laminae and streaks of heavy mineral concentrates associated with wedge-shaped cross bedding, intercalations of conglomerates with deep wash-outs on their bases, common channeling, etc.

Although the body fossils are almost absent in the Kosov Formation, abundant ichnofossils of great diversity, and with predominance of epistratal crawling, grazing and resting traces, point to diversified organic life. Body fossils, as said above, were removed by dissolution of calcareous shells. The contrast to the underlying Králův Dvůr Formation is very marked and drastic change in life conditions may be postulated. Generally, the sequence of pronounced, in all 10 sections studied uniform and evidently contemporaneous changes, already recognized by previous authors (Chlupáč 1951, Marek 1952, Bouček and Přibyl 1958) reflects a set of events in the topmost Králův Dvůr and lowermost Kosov Formations. These may be easily explained by cooling and contemporaneous eustatic regression and might reflect the onset of glacial period known from the northern part of Gondwana.

A marked shallowing near the base of the Hirnantian (Kosovian) stage, expressed by sharp and commonly erosional contacts of basal clastic or other regressive sediments, is known from many areas, e.g. north England and Wales, Norway (Oslo region) and Sweden, the Armorican Massif, the Carnic Alps, Spain and Portugal, north Africa (Morocco, Algeria, Libya), China, and elsewhere (see McKerrow 1979, Brenchley and Newall 1984, Brenchley 1984, Rong Jia-Yu 1984 a.o.). The rapid extinction of the rich Králův Dvůr fauna is comparable with a similar extinction event recognized generally near the lower Hirnantian boundary (Brenchley 1984) which can be correlated with a rapid onset of glaciation at the base of the Hirnantian (Kosovian). Due to a smaller distance of the glaciated areas at the Gondwana, the impact of cooling on the development of fauna was probably more severe in the Barrandian than in the more northern areas situated in temperate to warm Ordovician climatic zones.

The Ordovician-Silurian boundary Event

The base of the Silurian in the Barrandian is marked by an abrupt onset of graptolitic shales. The character of boundary beds is shown on fig. 6. Greenish-grey siltstones and claystones of the Kosov Formation are overlain by dark grey and even black graptolitic shales. The shales near the base are rich in sandy and silty admixtures. Lamination is preserved due to the lack of bioturbation. Black shales contain often more than 3 per cent of organic carbon and common disseminated pyrite. Somewhat higher in the sequence (see fig. 6) diachronous onset of siliceous shales with radiolarians can be observed. Siliceous shales up to silicites are formed mostly of microcrystalline silica and they contain as much as 5 per cent of organic carbon. Recent detailed studies of boundary sections by Š t o r c h (1982, 1985) offer a clear picture of this interval.



6. Three selected sections showing the Ordovician-Silurian boundary in different parts of the Barrandian (after P. Štorch, 1982, 1986)
Z. — Zone, C. — *Cystograptus*, Ak. — *Akidograptus*, D. — *Demirastrites*

The t o p m o s t l a y e r s o f t h e K o s o v F o r m a t i o n with abundant burrows (*Arenicolites* and *Planolites*) yielded at several places in the vicinity of Prague a typical, topmost Ordovician *Hirnantia* fauna with the index brachiopods *Hirnantia sagittifera* (McCoy), *Dalmanella testudinaria* (Dalman), *Leptaena rugosa* Dalman, *Kinnella kielanae* (Temple) a.o. brachiopod species were reported, trilobites *Brongniartella* *platynota* (Dalman), *Mucronaspis mucronata* (Brogn.), gastropods, nautiloids, hyolithids, crinoids, blastoids, conodonts, etc. including the graptolite *Glyptograptus bohemicus* Marek (Marek and Havlíček 1967, Havlíček and Marek 1973). According to Havlíček (1982), this assemblage belongs to a shallow subtidal life zone, Benthic Assemblage 3 to 4 in Boucot's (1975) sense.

The base of the Silurian graptolite shale facies falls biostratigraphically near the base of the *Parakidograptus acuminatus* Zone. The lower layers belong to the *Akidograptus ascensus* Sub-zone (corresponding to the lowest part of the *Parakidograptus acuminatus* Zone) and a complete sequence of lower Llandoverian graptolite zones is demonstrable particularly in the SE flank of the Barrandian. Absence of some zones in the NW flank and in some sections at Prague may be explained by local submarine erosion that, however, did not disturb the concordant layering of shale beds and usually was not accompanied by any marked erosional features (Štorch 1986).

The Ordovician-Silurian boundary is a transgressive and anoxic event. Many recent papers underline the coincidence between the sea level rise and the onset of anoxic environment. Thus black shale facies usually indicates a great and rapid transgression (e.g. Leggett 1980). The mechanism of the formation of the anoxic environment by sea level rise is not yet fully understood and several ways are suggested: e.g. formation of hypolimnion and stagnation of bottom waters, washing of great amounts of organic matter into the basin, the boom of planktonic life and poisoning of bottom waters with organic matter, flooding of source areas which limits the supply of terrigenous matter, etc. All these factors or one of them might have come into operation on the Ordovician-Silurian boundary.

The character of this boundary expressed in the lithology and fossil content points to a short-time event. Owing to slow rate of sedimentation of graptolitic shales (2—3 cm/1000 years) the world-wide and biostratigraphically well documented extent of this event is demonstrable at the same level on different continents (see Berry and Boucot 1973, McKerrow 1979, Brenchley and Newall 1984). Explanation by a rapid climatic change — warming causing a glacioeustatic rise of the sea level — seems to be the best and widely accepted (Berry and Boucot 1973 a.o.). Expressiveness and global character of the event clearly support the practical applicability of the new Ordovician-Silurian boundary accepted by the International Subcommission on Silurian Stratigraphy (comp. Holland 1984).

The Upper Kopanina Event

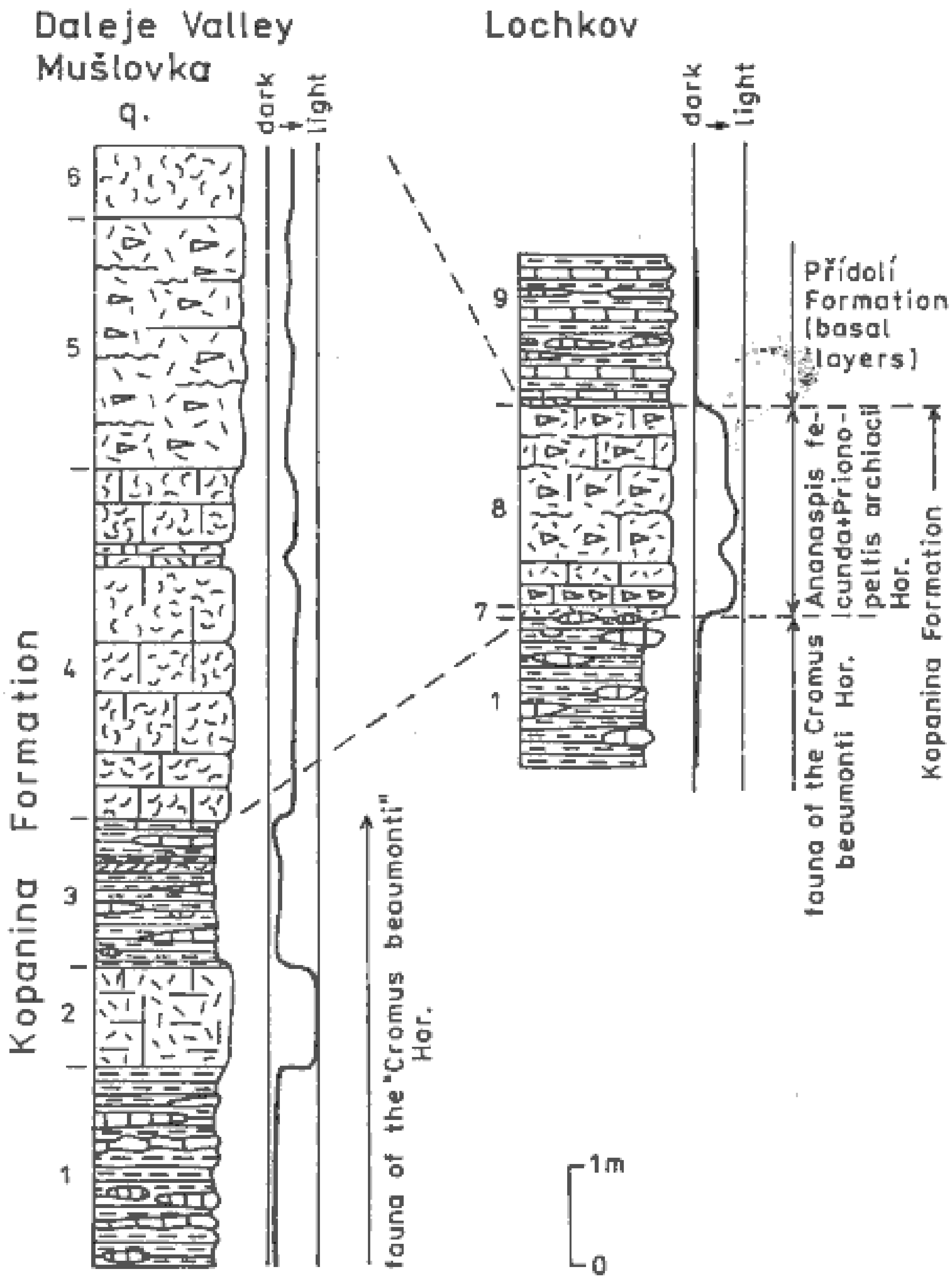
In studying the Mediterranean and central European Silurian sections, Jaeger (1976) came to a conclusion on an abrupt and ± coeval onset of carbonate sedimentation within the Ludlovian, namely above the *Saetograptus chimaera* Zone. This change in facies is clearly manifested in north Africa (Morocco, Algeria), Sardinia, Saxo-Thuringian region of central Europe; some analogies of this event are traceable in the eastern Alps, Spain, and elsewhere.

In the Barrandian, the facies development is strongly influenced by submarine volcanic activity in Wenlockian and Ludlovian times. Lavas, granulates and volcanic tuffs are fringed by a wide spectrum of biodetrital and biosparitic shallow water limestones. The individual limestone facies are distributed diachronically. In spite of that, a certain interval within the Ludlovian, namely from the base of the *Ananaspis fecunda* trilobite Horizon to the *Prionopeltis archiaci* Horizon deserves special attention. As already recognized by Horný (1955, 1962), a rather abrupt change in lithology and fauna is traceable in many sections. This change manifests itself sedimentologically by a decrease in insoluble residue and volcanic material content and by the onset of coarse and fine-grained biodetrital and even whole-skeletal Orthoceras limestones.

Biostratigraphically, the most important feature is the invasion of the widely distributed genus *Ananaspis* which becomes the index fossil being accompanied by many other new elements, e.g. trilobites *Coniproetus (Ryckholtia) ryckholti* (Barr.), *Interproetus intermedius* (Barr.), *I. venustus* (Barr.), *Decoroscutellum haidingeri* (Barr.). Graptolites are usually scarce in the biodetrital limestones of the level discussed, but assemblages of the zones with *Lobograptus scanicus (Monograptus chimaera)* and *Saetograptus linearis* were found below this level (Bouček 1936, Jaeger in Chlupáč et al. 1980, Přibyl 1983) and allow an approximate correlation with the level reported by Jaeger (1976). In the conodont biostratigraphy, this change falls within the *Polygnathoides siluricus* Zone (comp. Schönlaub in Chlupáč et al. 1980).

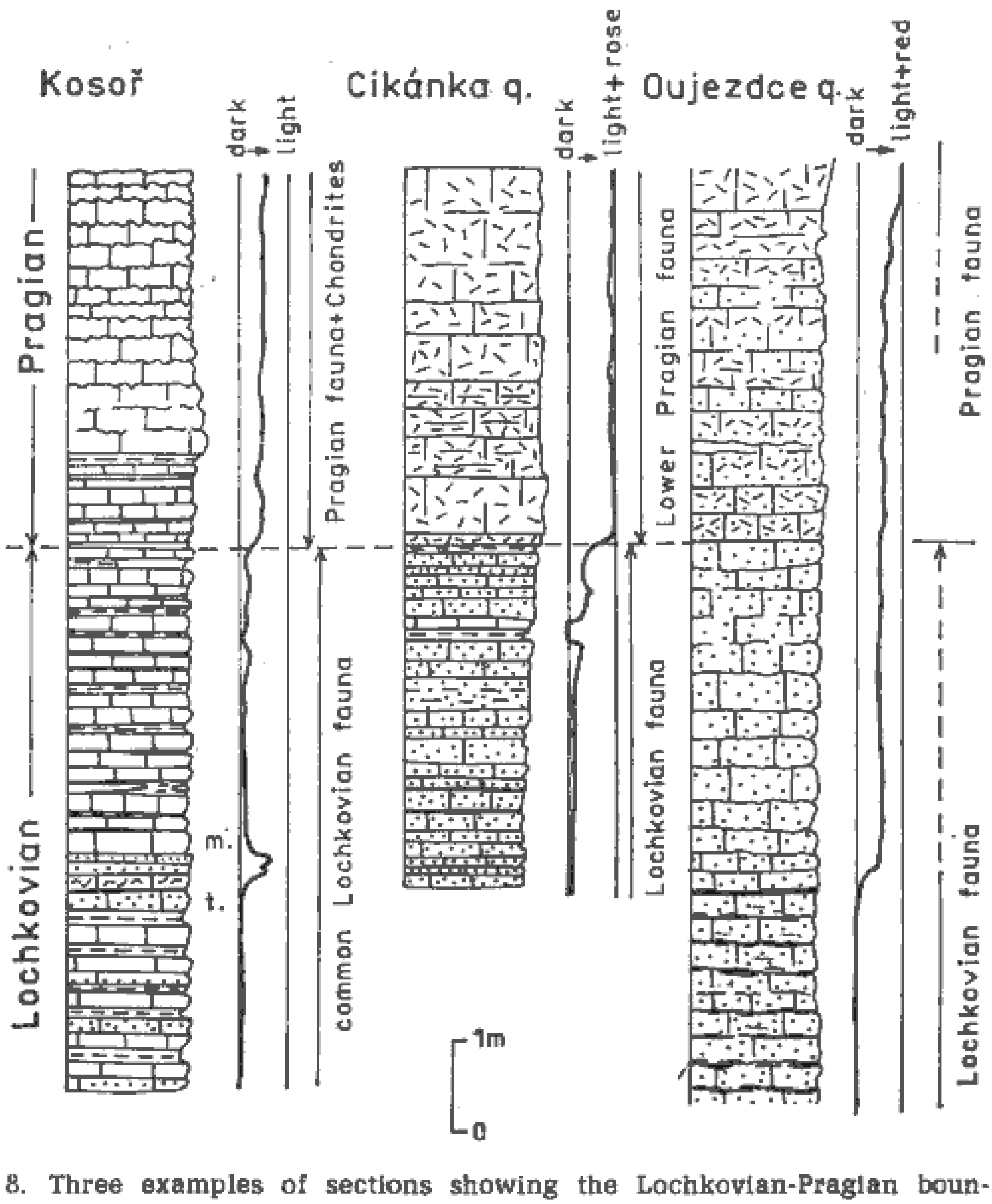
The character of this facies change points to a fall of sea level. This is in accordance with the presumed emersion of the Svatý Jan volcanic center in higher parts of the Kopanina Formation (Horný 1955, 1962). The regressive trend within the Ludlovian to which the discussed interval belongs, is widely recognizable

In the global scale (comp. Berry and Boucot 1980, 1973, McKerrow 1979 a.o.).



7. Two examples of Silurian sections showing the Upper Kopanina (Mid-Ludlovian) Event (supplemented after J. Kříž et al. 1980, 1983)
Hor. — Horizon, *1* — calcareous and tuffaceous shales and dark limestones with *Cromus (= Encrinuraspis) beaumonti*, *Diacanthaspis minuta*, etc.; 2 — biodetrital bank with *Metacalymene baylei; 3* — calcareous shale with *C. beaumonti* and *Monograptus (Saetograptus) fritschi linearis*, etc.; *4* — brachiopod limestones with *Dubaria megaera*, etc.; *5* — biodetrital cephalopod limestone; *6* — biodetrital limestone with *Dayia minor*, etc.; *7* — biodetrital limestone with *Ananaspis fecunda; 8* — biodetrital cephalopod ("Orthoceras") limestone; *9* — dark limestones and calcareous shales of the basal Přídolí Formation

change is very distinct in deeper-water facies (upper Lochkovian Radotín and Kosoř Limestones, lower Pragian Dvorce-Prokop Limestones, all with Benthic Assemblages 4 to 6 in Boucot's classification — see Chlupáč 1983). Shallow water facies at the same stratigraphic level shows also comparable change (upper Lochkovian Kotýs Limestone versus Pragian Koněprusy, Vinařice a.o. Limestones with Benthic Assemblage 3). The boundary effect in planktonic fauna is less distinct, but demonstrable (change in conodont, tentaculite, chitinozoan a.o. assemblages, see Chlupáč et al. 1985). Many relationships, however, can be found between the upper Lochkovian and lower Pragian fauna which document continuous evolution across this boundary.



8. Three examples of sections showing the Lochkovian-Pragian boundary Event·
Kosoř — Černá rokle, Cikánka quarry at Praha - Slivenec, Oujezdce quarry near Suchomasty

Evaluating all these lithologic and palaeontologic features and changes, the Lochkovian-Pragian boundary seems to reflect rather non-drastic, but relatively quick and synchronous event which can be explained by a fairly rapid but not very large lowering of the sea level. General shallowing of the basin can be proved by greater area occupied by shallow water biodetrital limestones in the lower Pragian and also by a growth of massive algal-stromatoporoid-coral reefs in the Koněprusy area. Overlying late Pragian limestones, however, reflect gradual deepening of the basin and a slow transgression (Chlupáč 1957).

An analogous change and tendency within the Lochkovian-Pragian boundary is shown in the Saxonian-Thuringian and Frankenwald regions, where grey Tentaculite Limestone (Tentaculiten-Knollenkalk) overlies the dark Lochkovian Upper Graptolite Shale (see Zagora 1978, Alberti 1981, 1983). In the Carnic Alps the dark platy Lochkovian limestones are followed by lighter-coloured reefal and other Pragian limestones in some sections (Schönlaub and Flajs 1975, Jaeger and Schönlaub 1980) and an analogous picture is clearly documented in north Africa (Morocco, Algeria, e.g. Rabat Tiflet, Tafilalt, Sidi Ahroun, Ben Slimane, Beni Afeur, etc., comp. Alberti 1969, 1981, 1983). Shallowing and carbonate influx near the Pragian base is described from Sardinia (Jaeger 1976, Alberti 1983) and the onset of carbonate sedimentation in many sections of the Armorican Massif (Paris 1981) may be also connected with the Basal Pragian Event.

In the western North America, the widely distributed break between the Lone Mountain Dolomite and its equivalents and the McColley Canyon Formation (plus its equivalents) also reflects the lower Pragian regressive Event (Johnson and Murphy 1984, Johnson et al. 1985). The regressive phase between the Helderberg and Ulster Groups (Pre-Oriscany) of the eastern North America (see Johnson et al. 1985) falls partly in the interval considered occupying evidently a greater time-span.

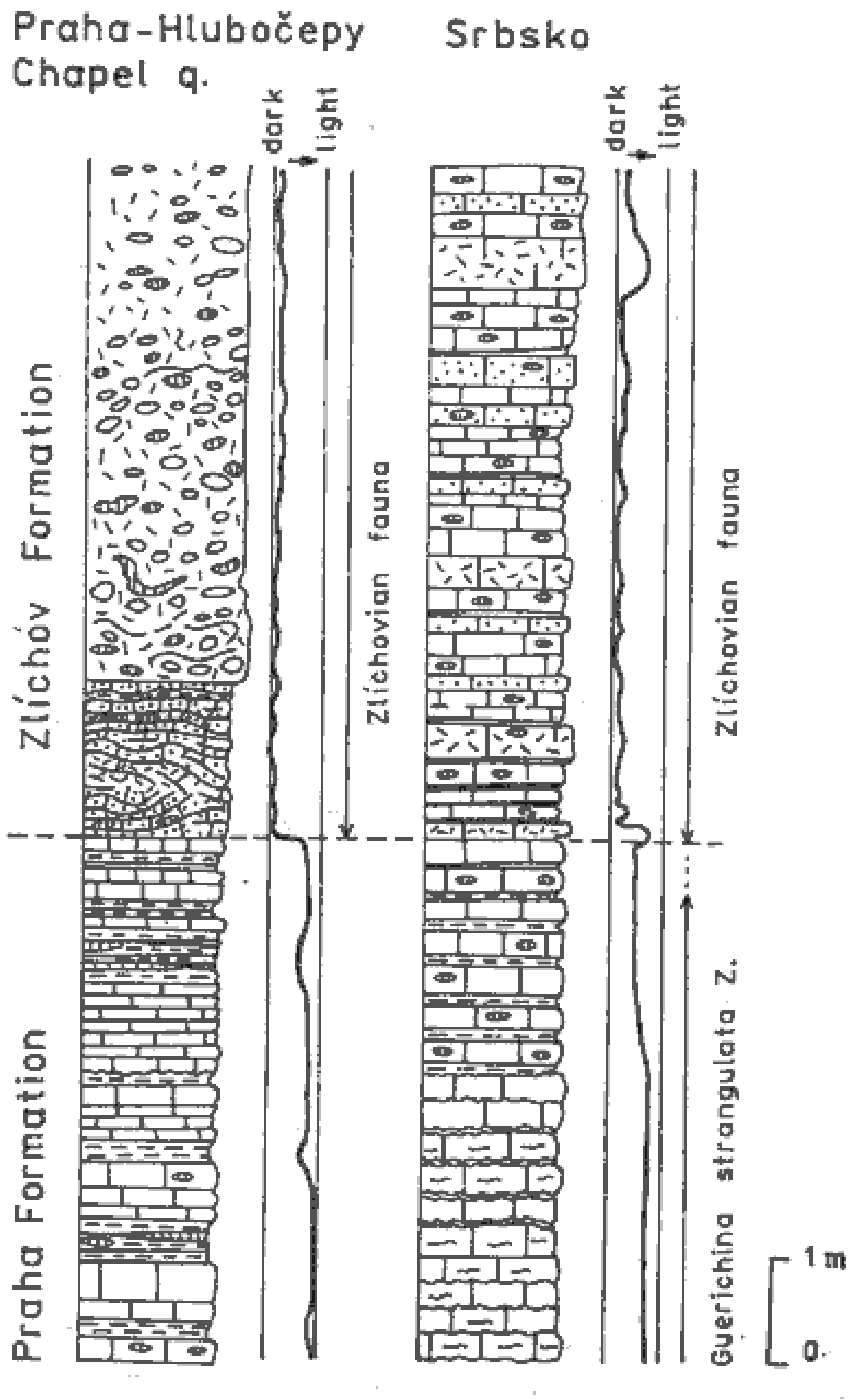
Generally, the Lochkovian-Pragian boundary Event seems to be of world-wide importance. It is best developed in the pelagic basinal sequence whereas it is masked by a great supply of terrigenous material in the nearshore clastic Rhenish development.

The Basal Zlíchovian Event

The base of the Zlíchov Limestone indicates an event which caused some lithologic and biostratigraphical changes. Sedimentologically, this event manifests itself differently in different parts of the basin.

In the SE flank of the Barrandian this change is most distinct. The Pragian micritic limestones are overlain by a coarse biodetrital limestone passing even into breccia consisting of coral, crinoid and stromatoporoid fragments, other bioclasts, diverse limestone and also chert clasts. Layers of this breccia are up to 8 m thick and repeat several times in the section. The breccia is mostly mud-supported and deformed by a slump structure.

In the central and SW part of the basin, the boundary is less distinct. It manifests itself by layers of coarse- and medium-grained biodetrital limestone which are embedded in micritic limestones. Bio-



9 Two sections showing the Basal Zlíchovian Event in different developments
Praha - Hlubočepy, roadcut near the Chapel quarry, Srbsko, roadcut s. of the village

detrital limestones contain re-worked and sorted mostly smaller bioclasts transported by strong currents from a shallow water environment.

In the NW flank of the basin the boundary is indistinct and falls within a sequence of grey, well bedded micritic limestones with interlayers of calcareous shales (e.g. localities Svatý Jan, Damil near Tetín).

A distinct change, as compared with the Pragian, can be observed in the basal Zlíchovian not only in the individual sections, but also in the general distribution of facies. In the Zlíchov Limestone, the biodetrital facies is developed in the NE and E parts of the basin (maximum thickness at Prague — more than 30 m), whereas the micritic facies is in the NW flank. Thus the situation is opposite to that in the Lower Pragian.

The Pragian-Zlíchovian boundary is biostratigraphically less distinct and lineages of different faunal groups seem to continue across the boundary interval. This can be observed both in shallow and deeper water environments.

As concerns the trilobites, the *Reedops-Odontochile* Assemblage persists from the Pragian into the lower Zlíchovian showing changes merely on the species level. Some lower Zlíchovian species are descendants of the Pragian ones (Chlupáč 1977, 1983). Some brachiopods show a similar picture, particularly Strophomenidina and chonetids (Havlíček 1969, Havlíček and Racheboeuff 1979).

In spite of the different spatial distribution of reefal and peri-reefal facies, the shallow-water Pragian and lower Zlíchovian assemblages show a great similarity in composition. The species in the Koněprusy (Pragian) and Chapel Horizons (Zlíchovian) are closely related or identical, particularly among tabulates, fenestellid bryozoans, brachiopods and crinoids. This is an expression of persistence of reefal assemblages in general.

Some new elements appear in the lower Zlíchovian, particularly in dacryoconarid tentaculites (*Nowakia zlichovensis* Zone), brachiopods and conodonts, but the distinct influx of new elements including the beginning of the world-wide development of goniatites falls into the higher parts of the Zlíchovian.

Trace fossil assemblage of micritic limestones dominated by ubiquitous *Chondrites* persists from the late Pragian into the Zlíchovian. The boundary interval is characterized by a rich development of *Zoophycos.*

All the described changes accompanying the base of the Zlíchovian clearly correspond to some local events. In the SE flank of the Barrandian there was a distinct shallowing which resulted also in the erosion of the underlying limestones and deposition of thick layers of limestone breccias. Local tectonics seems to be responsible for this shallowing.

The Daleje Event

Great change in sedimentation occurred in the topmost Zlíchovian. Here, the Daleje Shale, consisting mainly of calcareous shales, became the typical facies. Moreover, general change in sedimentation can be observed over the whole territory of the Barrandian (more than 15 sections studied, Chlupáč 1959, Chlupáč et al. 1979).

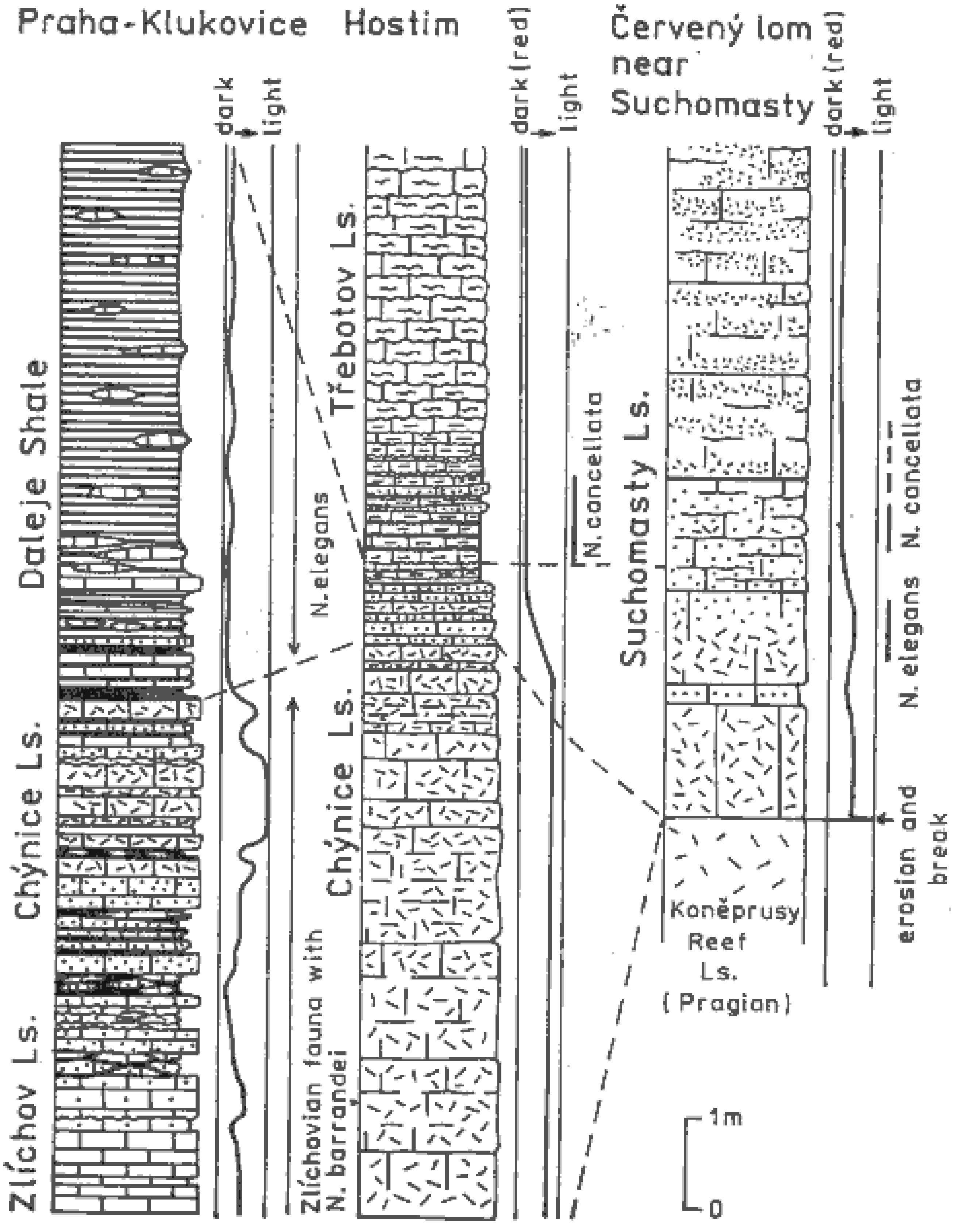
In the greatest part of the Devonian of the Barrandian, the sections of the uppermost Zlíchov Limestone show the gradually increasing amount of interlayers of grey-greenish calcareous shales within the beds of biomicritic limestone. This sequence corresponds to the late Zlíchovian *Nowakia barrandei* tentaculite Zone (see classic sections in Praha-Zlíchov, Pekárkův mlýn near Solopysky, Choteč, Karlštejn, etc). Within the topmost Zlíchovian Zone with *Nowakia elegans* the shale beds start to dominate over limestones which are reduced to thin intercalatios and lenses only.

In the NW flank and SW part of the Devonian basin, the topmost Zlíchovian is developed as reddish, medium- and coarse-grained biosparitic, crinoidal, well sorted limestone (Chýnice Limestone) which belongs to the upper part of the *Nowakia barrandei* up to the *N. elegans* Zones. Near to the upper Zlíchovian limit the Chýnice Limestone is rather sharply overlain by greenish or reddish calcareous shales with micritic nodules (e.g. Bubovice), or by red nodular micritic limestone of the lowest part of the Třebotov Limestone of the lowest Dalejan *Nowakia cancellata* Zone (e.g. Hostim).

The Koněprusy area shows a special development: Basal layers of reddish biomicritic and biosparitic Suchomasty Limestone with proved *Nowakia elegans* Zone at its base transgress here after a significant break over the Pragian reef complex of the Koněprusy Limestone. Intensive erosion of the reef surface can be seen on the contact. The emerged reef surface was subjected to karst weathering and a network of open fissures developed which was subsequently filled with the material of the Suchomasty Limestone. The fissures re-opened later and were filled again in several phases by younger material (see Chlupáč 1955, Chlupáč et al. 1979).

Biostratigraphically, the faunal changes near the upper Zlíchovian boundary fall into the interval of the *Nowakia barrandei* — *N. elegans* —

N. cancellata tentaculite Zones which correlate with the upper part of the *Polygnathus gronbergi* to *P. laticostatus* conodont Zones (K l a p p e r et al. 1978, C h l u p á č et al. 1979). The faunal changes are very gradual (except the Koněprusy area): Among trilobites, the topmost Zlíchovian *Phacops-Pilletopeltis* Assemblage passes into the Dalejan *Phacops-Struveaspis* Assemblage by disappearance of some elements



10. Three sections showing the Daleje Event in different facies developments
Praha - Klukovice (outcrop at the former railway station), Hostim (w. of the village), Červený lom near Suchomasty (Koněprusy reef area). Ls. — Limestone, N. — *Nowakia*

(e.g. *Phacops (Ph.) degener* (Barr.), *Reedops decorus* (H. et C.), *Odontochile* div. sp.) and their replacement by new ones (e.g. *Phacops (Ph.) superstes superstes* (Barr.), *Cyrtosymboloides superstes* (Barr.)]. There is also a close relationship between the late Zlíchovian and Dalejan *Orbitoproetus-Scabriscutellum* Assemblages (they occur in biodetrital Chýnice and Suchomasty Limestones) (comp. Chlupáč 1983). This points again to a gradual change. The development of other benthic, planktonic and nektonic biotas shows a similar picture of a gradual change (in goniatites extinction of *Anetoceras,* persistence of *Mimagoniatites fecundus,* and the influx of new species of *Teicherticeras,* etc., comp. Chlupáč and Turek 1983, overlapping of zonal index fossils, e.g. tentaculites). The ichnofossil assemblages dominated by ubiquitous *Chondrites* in all micrites and calcareous shales remained unaffected.

Reviewing the Dalejan-Zlíchovian boundary interval in general, the gradual character of the changes is expressive. In sections where fine-grained sediments of low-energy environments occur, the interval of change occupies several meters, whereas in those with biodetrital and more condensed limestones the change embraces much lesser range but is gradual as well.

The character of the change points to a gradual rise of the sea level. Its result was most conspicuous in the Koněprusy area, where the raised Pragian reef complex was drowned. The onset of clayey sedimentation of the Daleje Shales can be also explained by the deepening of the basin, slowing down of the carbonate sedimentation and intensive influx of the terrigenous fine siliciclastic material from the east. In the NW flank of the basin, the episodic coarser influx of biodetrital material (Chýnice Limestone) was replaced by deeper water sedimentation of calcareous shales and micritic limestone near the Dalejan base.

Changes of analogous character in a correlatable stratigraphic level are known from north Africa (Morocco and Algeria — retreat of the reefal and other carbonate facies and onset of deeper water Rahal Shale and its equivalents — Alberti 1969, 1970, 1981a,b), the Asia Minor, Bithynia (retreat of shallow water facies and onset of the Bohemian faunas near the Dede-Gebze Formations boundary — Haas 1968), N. Spain, Palencia (clayey influx in the lower part of the Arauz Formation, particularly at the top of the Requejada Member — Jahnke et al. 1983, Henn 1985), Armorican Massif (facies change near the base of the Marettes and Marollières Formations and the Traon Group, Paris 1981).

In the sections in central Asia (Tian Shan, Khodzha Kurgan), the distinct deepening near the Kimovsk-Dzhausk Formations falls here (Kim et al. 1978). In some sections in southern China (Nandan, SE Yunnan), the Napiao and Pozeluo Formations are characterized by a new faunal influx (Yang et al. 1981). A distinct deepening of the basin during the roughly same time is shown from Novaya Zemlya where the dark carbonates of the Pakhtusov Formation with the upper Zlíchovian to Dalejan goniatites and conodonts overlie the shallow water limestones (Čerkesova et al., Nechoroševa et al., in Sokolov - Ržonsnickaja 1982).

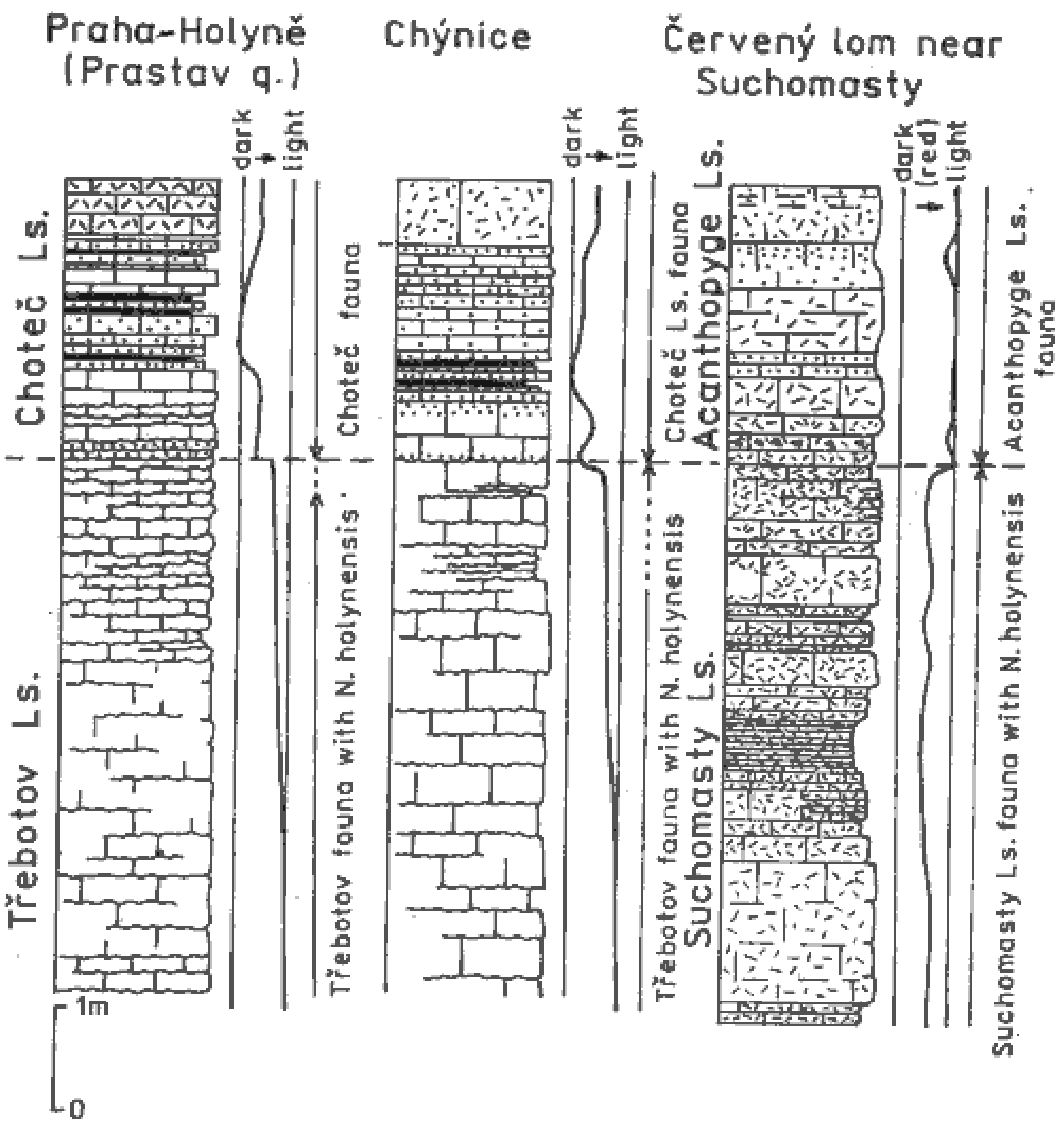
The deepening in the corresponding stratigraphic level was clearly recognized by Johnson et al. (1985) in the western US, western Canada and New York. They place it within their cycle Ib.

Recently House (1985) paid attention to the event character of this level stressing its expressiveness in the ammonoid development (extinction of *Mimosphinctidae* and *Auguritidae* is clearly demonstrated in the Barrandian sections — Chlupáč and Turek 1983). The difference of Upper Emsian faunas from those of the Lower Emsian demonstrated even in the clastic Rhenish development (Solle 1972) and particularly the **decrease in provinciality** in the Dalejan (Late Emsian) faunas may by influenced by this event. From the above discussion it follows that the Daleje Event has a global character and manifests itself by a gradual rise of sea level, deepening of basins which were often accompanied by clay deposition at the expense of carbonate sediments.

The Basal Choteč Event

The boundary between the Třebotov and basal layers of the Choteč Limestones and their equivalents may point according to biostratigraphically evidenced stable level and lithologic + paleontologic evidence to a rather important event. This level is situated in the Barrandian slightly above (usually less than 3 m) the recently newly internationally defined Lower-Middle Devonian boundary, drawn according to the base of the *Polygnathus costatus partitus* conodont Zone (Ziegler and Klapper 1982). The interval was studied in the Barrandian in more than 10 sections (Chlupáč 1959, 1982, Klapper et al. 1978, Chlupáč et al. 1979).

The Třebotov-Choteč boundary falls within the continuous limestone sedimentation. The base of the Choteč Limestone is characterized by abrupt onset of darker coloured biomicritic and biosparitic limestone layers within lighter micritic limestones. Upwards, usually within an interval of 1—2 m, the amount of darker biosparites increases and micritic layers become also darker. Thin intercalations of dark calcareous shale appear. The change in colour is usually gradual; the trend to a darker colour is observable already in topmost 1 to 2 m of the Třebotov Limestone below the first biosparite layer of the Choteč Limestone. In the shallow water development in the Koněprusy area, the biostratigraphically correlatable level represents the Suchomasty-Acanthopyge Limestones boundary. It is characterized by an onset of basal biosparitic and aggregate (grapestone) carbonates of the Acanthopyge Limestone (locally with sedimentary breccia) sharply overlying the reddish-grey biomicritic up to biosparitic crinoidal Suchomasty Limestone.



11. Three sections with effects of the Basal Choteč Event
Praha - Holyně, Prastav quarry (Lower-Middle Devonian boundary parastratotype), Chýnice (outcrops near the former Jelínkův mlýn), Červený lom near Suchomasty (Koněprusy area). Ls. — limestone, N. — *Nowakia*

Biostratigraphically, this level is characterized by a clear faunal change: new forms appear among trilobites — e.g. *Leonaspis pigra* (Barr.), *Aulacopleura bohemica* (Přib.), *Koneprusites* div. sp., *Cyphaspides holynensis* Růž., *Phaetonellus planicaudus* (Barr.), *Struveaspis fugitiva* (Barr.) a.o., goniatites *Agoniatites (Fidelites) occultus* (Barr.), *A. (F). fidelis* (Barr.), *Pinacites jugleri* (Roem.) a.o., the index dacryoconarid tentaculite *Nowakia sulcata sulcata* (Roem.), conodonts, brachiopods, nautiloids, etc., whilst many forms of the underlying Třebotov and Suchomasty Limestones become extinct (see Chlupáč et al. 1979, Chlupáč 1982, 1983, 1985). In the zonal subdivision, this level roughly corresponds to the boundary between the tentaculite Zones *Nowakia holynensis-N. sulcata sulcata* and conodont "lineage" Zones *Polygnathus costatus partitus-P. c. costatus.*

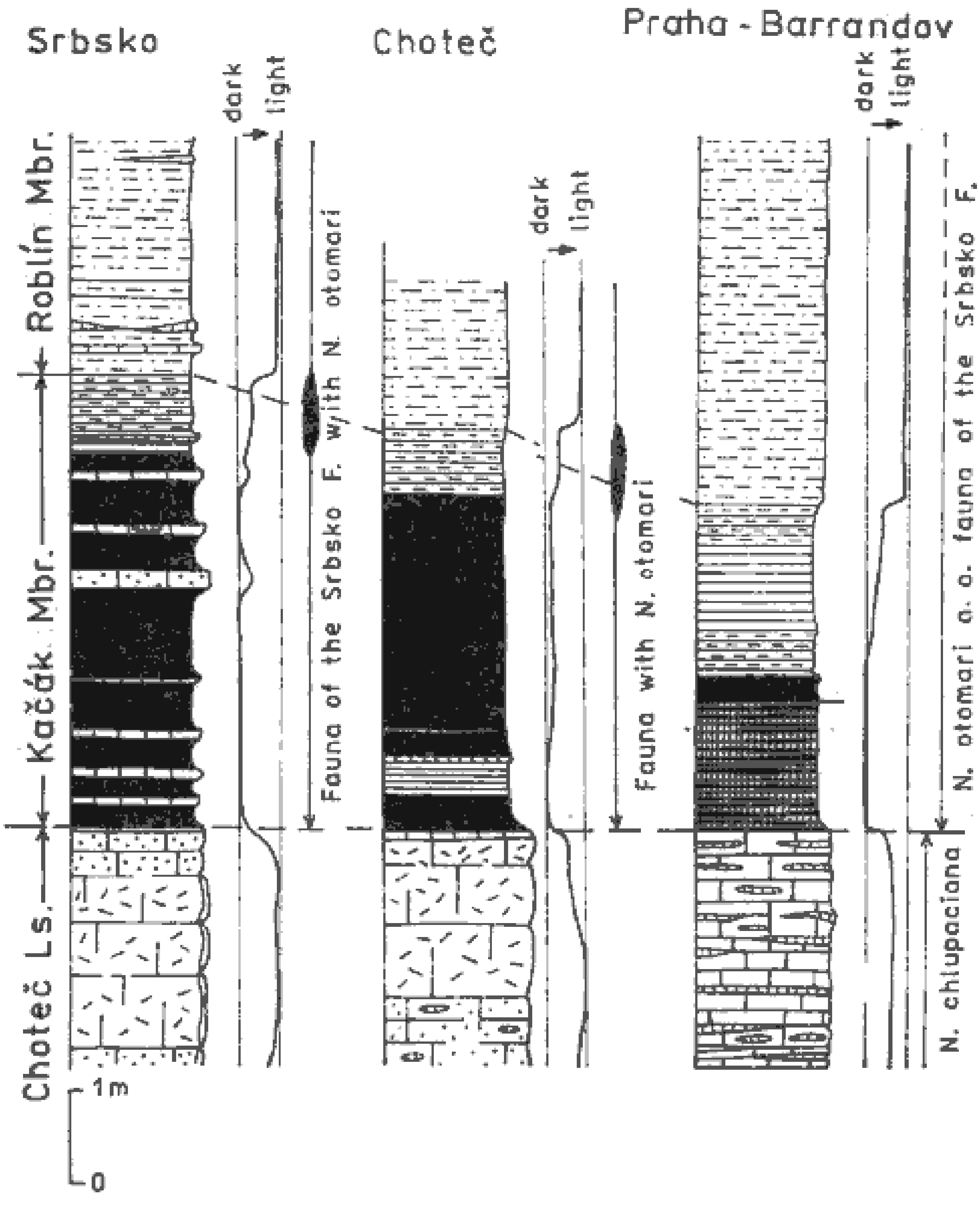
The synchronousness of the onset of biosparite layers of basal Choteč (Acanthopyge) Limestone in the Barrandian sections is biostratigraphically evidenced. Change in colour and increase in organic carbon content point to gradual onset of partly anoxic conditions caused by a deepening of the basin. Even though the change in sediments and fauna seems to be abrupt, some gradual character can be observed; some new faunal elements appear already below the first distinct biosparitic layer of the Choteč (or Acathopyge) Limestone.

Correlatable change in lithology and fauna is distinctly expressed in many Devonian regions with pelagic limestone facies: in north Africa (Morocco — Alberti 1980), Rheinisches Schiefergebirge and Harz Mts. (Requadt and Weddige 1978, Alberti 1980), Thuringia and Frankenwald (the base of the Schwärz Shale — Alberti 1980), Armorican Massif (the base of the St. Fiacre Formation, Morzadec 1983), N. Spain (the base of the La Loma Member — Jahnke et al. 1983, Henn 1985), the Ural Mts. (upper limit of the *Zdimir pseudobaschkiricus* Biozone — Sapelnikov and Mizens 1980). Event-character of this level might positively influence the wide recognition of the base of the *Polygnatus costatus costatus* conodont Zone (comp. Klapper and Johnson 1980, Johnson et al. 1985). The extent of recognition of the level discussed evidently depends on the degree of exact biostratigraphic studies.

The Kačák Event

The boundary between the Choteč Limestone and the overlying Kačák Shale Member of the Srbsko Formation belongs to the sharpest stratigraphical boundaries in the Barrandian. The base and development of the Kačák Member show a remarkable persistence in all the 15 sections studied being thus an important stratigraphic horizon (Chlupáč 1960).

The Choteč-Kačák boundary is distinct by its change in sediments: the underlying Choteč Limestone is developed as thinly bedded biomicritic and micritic limestone with bedded cherts (NE part of the basin) or as light grey thick bedded coarse biosparitic limestone (SW part). It is overlain by dark clayey shales (slightly silty with



12. Examples of sections with effects of the Kačák Event
Srbsko (classic Jahn's locality n. of the village), Choteč (ne. of the village near the U Veselých farm), Praha - Barrandov (highway roadcut). Ls. — Limestone, Mbr. — Member, F. — Formation, N. — *Nowakia*

calcareous admixture) of the Kačák Member (total thicknesss is 2 to 15 m). The content of org. C may reach 1.5 per cent, disseminated pyrite is also common. In some sections (NE part of the basin) layers of a bituminous clayey limestone appear within the shales of the Kačák Member and also thin layers of siliceous shales and clayey silicites (radiolarites) can be found (Praha-Hlubočepy a.o.).

Upwards the clayey shales of the Kačák Member become greyish and brownish, the amount of quartzose silt is irregularly increasing together with larger organic remains. Kačák Shales are more or less sharply overlain by siltstones, clayey siltstones, and even sandy siltstones of the Roblín Member which show a typical flyschoid character.

The Choteč-Kačák limit represents a marked biostratigraphic boundary. It corresponds to the limit between the *Nowakia chlupaciana* (below) and *N. otomari* (above) Zones in the tentaculite zonation and to an abrupt change in other groups. The invasion of goniatites of Givetian character, e.g. *Agoniatites* of the *costulatus* and *vanuxemi* groups, common *Holzapfeloceras*, and the index *Cabrieroceras crispiforme* are characteristic. Benthic forms display also a remarkable change: common trilobites of the Choteč Formation (incl. the *Acanthopyge* Limestone — about 50 species known) are reduced to two rare species in the Kačák Member. Prolific brachiopods (about 40 species in the Choteč Formation) are reduced to few forms among which only inarticulates (Orbiculoidea) are frequent and an analogous decline is shown in other benthic animals. Planktonic and nektonic elements were less affected, but their faunal diversity becomes markedly lesser (dark Kačák Shales, contain dacryoconarid tentaculites, nautiloids, goniatites, small, probably epiplanktonic bivalves, radiolarians, sponge spicules and only subordinate small brachiopods, etc.). About 250 species are described from the Choteč Formation, whereas only about 60 from the Kačák Member. This difference is still accentuated by the fact, that the prevalent part of the subordinate benthic forms of the Kačák Member is concentrated in its upper parts where the life conditions markedly improved (comp. development in all the sections studied, Chlupáč 1960). Chondrites are prolific in some layers.

In the conodont biostratigraphy, the Choteč-Kačák boundary falls within the upper part of the *Tortodus kockelianus kockelianus* Zone, evidently not far from the base of the *Polygnathus ensensis* Zone.

The general character of this boundary points to a rapid and great change in the environment which is explained most likely by a quick rise of the sea level. The basin deepening was accompanied by an onset of anoxic conditions. In its expressiveness, this limit is comparable with the Ordovician-Silurian boundary.

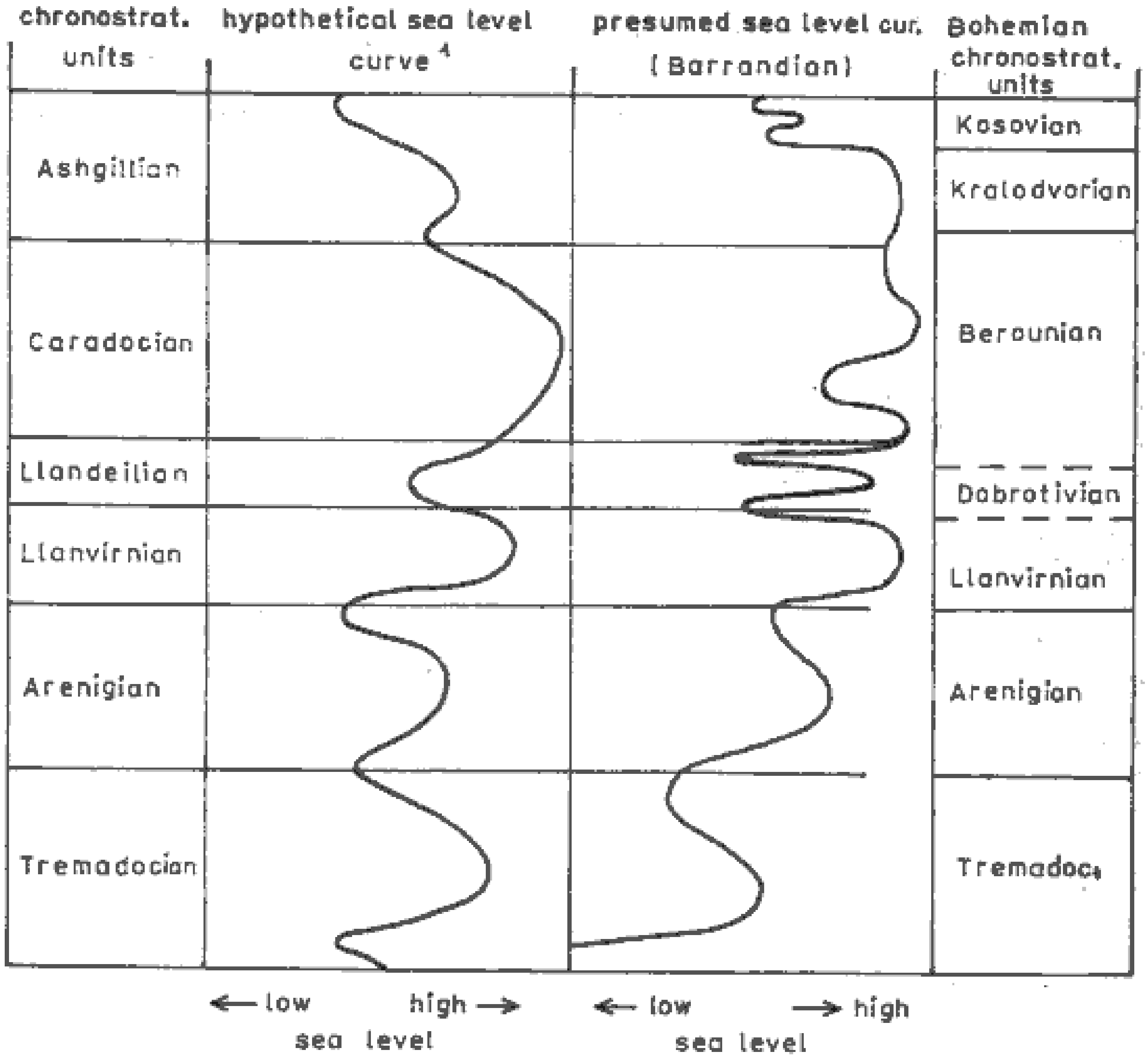
Analogous change in facies and fauna was recognized in many other areas. In the Ardenno-Rhenish area, a distinct influx of Bohemian (Hercynian) facies with the dark Odershausen Limestone falls in a correlatable level (Goldring et al. 1978, Krebs 1978). In some north African sections it is documented by dark shales with Nowakia otomari (comp. Alberti 1980, 1983) and the same is true for s. China (Yang et al. 1981). In the classic New York sections of the eastern North America, the onset of the Union Spring Shale with the Cherry Valley Limestone correlates with the Kačák Event and in the western North America the abrupt transgression near the base of the *Polygnathus ensensis* Zone (as one of the pre-Taghanic onlap transgressions) falls in the same broader interval (Johnson and Murphy 1984, Johnson et al. 1985). In the scheme of Devonian eustatic fluctuations presented by Johnson et al. (1985), this event falls within the interval of cycles Ie and/or If.

House (1985) recognized the importance of the Kačák Event for the evolution of goniatites (wide distribution of *Cabrieroceras,* onset of *Tornoceratina,* decline in diversity of anarcestids, etc.), which would be in the ammonoid biostratigraphy the "natural" base of the late Middle Devonian *("Maenioceras Stage").* Wide and even intercontinental distribution of the Kačák dacryoconarid tentaculite fauna with the index *Nowakia otomari* and allied forms shows analogous patterns of distribution and biostratigraphic significance.

Conclusion

Contemporaneous trends in the stratigraphy can be characterized mainly by a search of global events enabling world-wide correlation of stratigraphic sequences. Our research was carried out in order to recognize and characterize such events in the classic Palaeozoic sequence of the Barrandian. The detailed characteristics of the Barrandian events is given in the text and summarized in the table 3. There, the following classification of events is used: a) according to lithologic and faunal changes (sharp or gradual), b) according to the origin (eustatic, tectonic or other controls), c) according to the extent (local or global character), d) according to some other characteristic features.

The most distinct events of clearly global character are as follows: The Middle Cambrian transgression, the

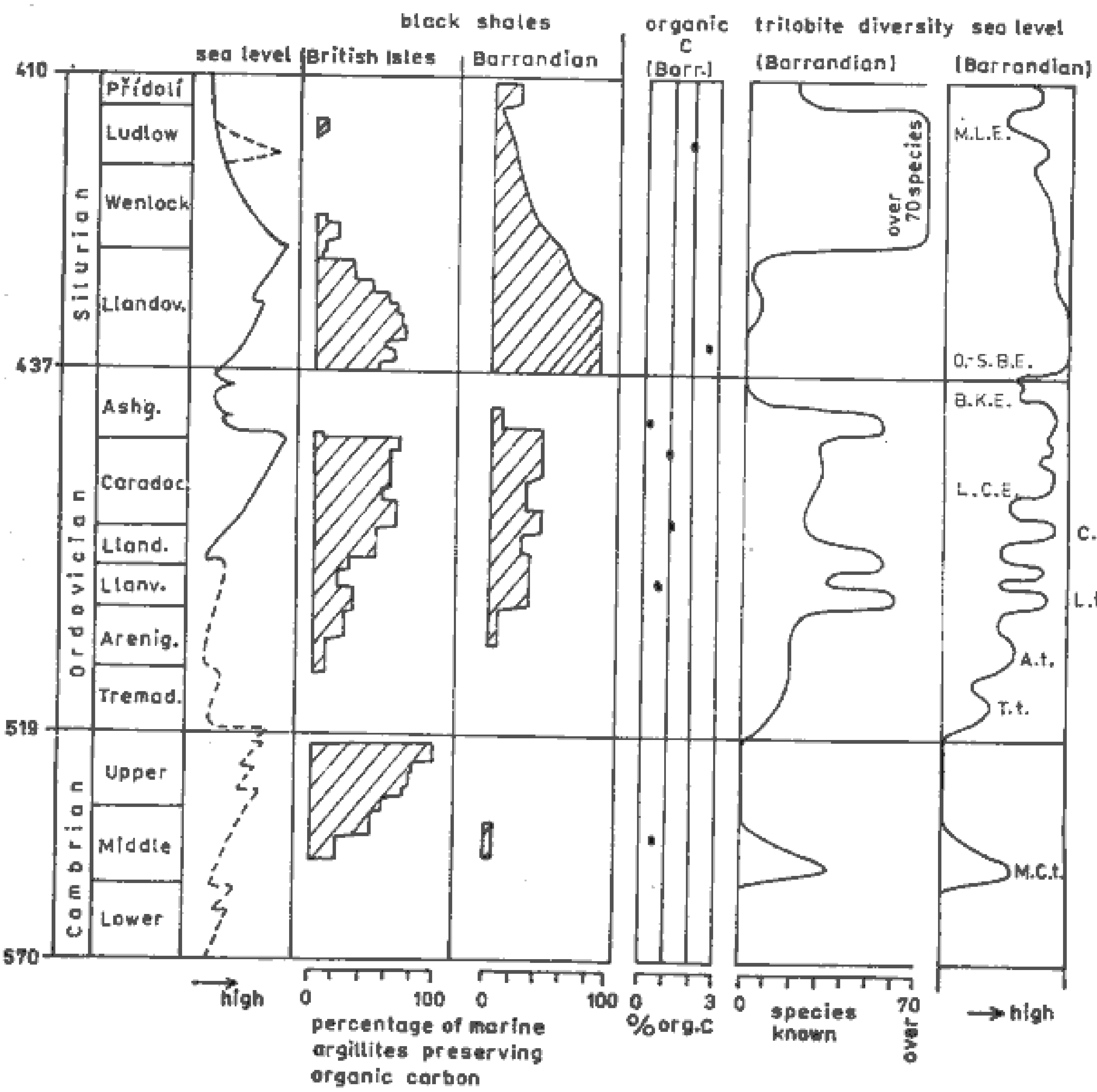


13. A comparison of the hypothetical sea level curve[1] (after R. A. Fortey 1984) with presumed sea level oscillations deduced from the Barrandian Ordovician

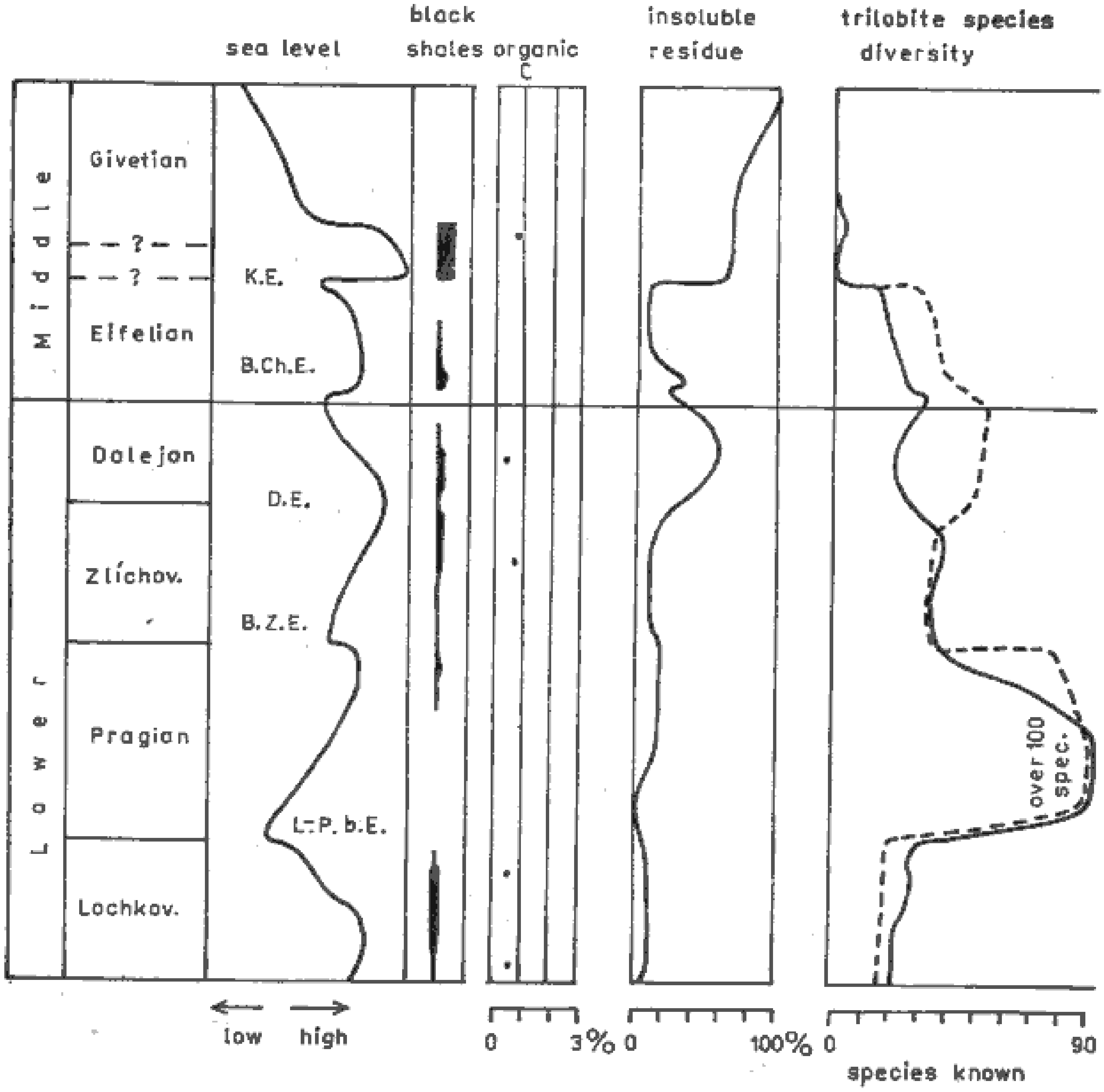
Ordovician-Silurian boundary Event and the **Kačák Event**. In the last two cases the events can be characterized by a rather sudden transgression and onset of anoxic conditions. In the first case the more gradual transgression caused an onset of marine environment over the continental one.

Within the set of events of **presumed global character**, the following ones are included: The **Late Cambrian regression**, the **Tremadocian transgression**, the **Llanvirnian transgression**, the **Basal Kosov regressive Event**, the **Lochkovian-Pragian regressive Event**, the **Daleje transgressive Event**, the **Choteč transgressive Event**. The transgressive events of this category are connected with the onset of anoxic environment and the immigration of new faunal elements, whereas the regressive events mean a far wider distribution of coarser siliciclastic or carbonate biodetrital sediments and development of shallow water fauna.

The next category of events shows some evidence of regional distribution, but their global character is questionable; the following events are included: The Lower Caradocian transgressive Event, the Upper Kopanina regressive



14. Sea level curve and black shale occurrences from the British Isles and the Barrandian completed by org. C content in black shales and trilobite diversity in the Lower Paleozoic (Cambrian-Silurian) of the Barrandian. The data from the British Isles are after J. K. Leggett et al. (1981)
M.C.t. — Middle Cambrian transgression, T.t. — Tremadocian transgression, A.t. — Arenigian transgression, L.t. — Llanvirnian transgression, C.t. — Caradocian transgression, L.C.E. — Lower Caradocian Event, B.K.E. — Basal Kosov Event, O.-S.B.E. — Ordovician-Silurian boundary Event, M.L.E. —Mid-Ludlovian (Upper Kopanina) Event



15. Presumed sea level curve for the Devonian of the Barrandian. It is accompanied by the data showing black shale occurrences, average content of insoluble residue and trilobite species diversity (*full line* — diversity in deeper water facies, *dashed line* — diversity in shallow water bioclastic and reefal facies)
L.-P.b.E. — Lochkovian-Pragian boundary Event, B.Z.E. — Basal Zlíchovian Event, D.E. — Daleje Event, B.Ch.E. — Basal Choteč Event, K.E. — Kačák Event

Event, and the Basal Přídolian transgressive Event. With these events pronounced lithological and faunal changes are connected, but they cannot be classified as world-wide, even though a future research and more detailed stratigraphic correlation might rise their importance.

The last category of the events can be called as local; as a suite of the Mid-Ordovician transgressive and regressive

Table 3

Characteristics, origin and global importance of the Barrandian events

Event	Boundary character			Control		Global importance			Remarks
	sharp	gradual within <3m	gradual within >3m	Eustatic	Tectonic	local → global			
14. Kačák	+			+				+	dark shales
13. Basal Choteč		+		+			+		organic-rich sediments
12. Daleje			+	+			+		siliciclastic sediments
11. Basal Zlíchovian	+	+			+	+			change in facies distribution, local breccia
10. Lochkovian-Pragian boundary	+	+		+			+		onset of biothermal and coarse biodetrital limestones
9. Basal Přídolian	+	+		+	+		+		dark laminites
8. Upper Kopanina	+	+		+		+			locally volcanic control
7. Ordovician-Silurian boundary	+			+				+	graptolitic shales
6. Basal Kosov	+			+			+		conglomerates, impoverishment in fauna
5. Low Caradocian	+	+		+	?		+		iron ores, black shales
4. Mid-Ordovician	+	+		+	+	+			
3. Llanvirnian transgression	+			+			+		black shales
2. Tremadocian transgression	+			+	+		+		marine transgression
1. Middle Cambrian regression transgression			+ +	+ +			+	+	continental deposits marine deposits

events and the Basal Zlíchovian Event. They seem to be affected by a local tectonics.

Volcanic activity could have affected particularly the Upper Kopanina regressive Event but it did not have a full control on it.

The present state of biostratigraphy does not allow to fully evaluate an importance of all the events and there is even a possibility of a discovery of some other turning points of the event-character in the Barrandian and other areas.

K tisku doporučil V. Havlíček
Přeložili autoři

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Události globálního významu a stratigrafie barrandienského paleozoika (kambrium–střední devon)

(Résumé anglického textu)

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Vysoký stupeň geologické i paleontologické prozkoumanosti paleozoika Barrandienu umožňuje aplikace nového směru ve stratigrafii — tzv. eventostratigrafie, která se na základě komplexního výzkumu vrstevních sledů a jejich korelací snaží odkrýt významné, ba až převratné události v geologické historii.

Ve starším paleozoiku Barrandienu byly na základě podrobného biostratigrafického a sedimentologického studia zjištěny tyto významné mezníky ve stratigrafickém vývoji, které mají charakter událostí („eventů") a z nichž mají širší, příp. i globální význam:

1) Raně středokambrické transgrese a pozdně středokambrická regrese, 2) tremadocká transgrese, 3) llanvirnská transgrese, 4) skupina transgresívních a regresívních událostí ve středním ordoviku (llandeil až spodní caradok), 5) spodnocaradocká transgresívní událost (v Barrandienu poněkud opožděná proti jiným oblastem), 6) regresívní událost na bázi stupně kosovu, 7) transgresívní událost na hranici mezi ordovikem a silurem, 8) svrchnokopaninská regresívní událost uvnitř ludlowu, 9) transgresívní událost na bázi stupně přídolu, 10) regresívní událost na hranici stupňů lochkov—prag ve spodním devonu, 11) událost v bazální části zlíchovu, 12) dalejská transgresívní událost v hraničních vrstvách zlíchov—dalej, 13) transgresívní událost na bázi chotečského souvrství (ve spodním eifelu) a 14) kačácká transgresívní událost na bázi kačáckých vrstev (srbského souvrství) středního devonu.

Transgresívní události jsou většinou spjaty s nástupem anoxických podmínek i nástupem nových faunistických prvků se značným korelačním potenciálem. Jednotlivé události lze charakterizovat z hlediska jejich globálního či lokálního charakteru, který je ovšem ovlivněn stupněm i přesností současných stratigrafických korelací i metod. Události globálního rozsahu lze podle našeho názoru nejlépe vysvětlit eustatickými změnami mořské hladiny.

K nejvýraznějším událostem globálního charakteru, které se odrazily ve stratigrafickém sledu paleozoika Barrandienu, lze řadit středokambrickou transgresi, událost na hranici mezi ordovikem a silurem a kačáckou transgresívní událost. Dvě poslední události se vyznačují náhlou transgresí (prohloubením moře) a nástupem anoxických podmínek, středokambrická transgrese reprezentuje nástup mořského prostředí po dlouhém období kontinentální sedimentace.

Nepochybně globální, avšak poněkud méně výrazný charakter mají události kladené do další skupiny, a to pozdně středokambrická regrese, tremadocká transgrese, llanvirnská transgrese, regresívní událost na bázi kosovu, regresívní událost při hranici lochkovu a pragu, dalejská transgresívní událost a transgresívní událost na bázi chotečského souvrství. Snad do této skupiny patří i spodnocaradocká transgresívní událost, která má globální charakter, avšak její nástup je v Barrandienu poněkud zpožděn. Transgresívní události této skupiny jsou spojeny s nástupem anoxických podmínek a imigracemi nových faun, zatímco regresívní události se vyznačují širším rozšířením siliciklastických nebo biodetritických sedimentů s faunami mělkovodního rázu.

Další skupina událostí má sice průkazně větší geografické rozšíření i mimo Barrandien, avšak globální charakter je sporný. Řadíme sem regresívní událost ve svrchní části kopaninského souvrství a transgresívní událost na bázi stupně přídolu. I když jsou litologické i faunistické změny na těchto úrovních výrazné, nedovoluje současný stav stratigrafických korelací považovat tyto události za globální, i když budoucí výzkumy mohou prokázat jejich širší význam.

Do poslední skupiny událostí řadíme sice výrazné, ale spíše místně podmíněné změny, které mohly být vyvolány nebo alespoň ovlivněny místním tektonickým režimem. Je to skupina transgresívních a regresívních událostí ve středním ordoviku a událost v bazální části zlíchovu.

Vulkanická činnost mohla ovlivnit zejména regresívní událost ve svrchní části kopaninského souvrství, avšak zřejmě nebyla jejím důvodem, neboť geografický rozsah účinků této události daleko přesahuje oblast Barrandienu.

Rozpoznání a ocenění událostí dovolují jen podrobné biostratigrafické korelace a litostratigrafické srovnání širokých oblastí. Je zřejmé, že další pokrok v korelacích přinese zjištění dalších významných událostí ve stratigrafickém vývoji Barrandienu i jiných oblastí.

Vysvětlivky k tabulkám

Tabulka 1. Klasifikace mimořádných událostí, která je založená hlavně na jejich délce (podle Ch. Pomerola 1984, upraveno).

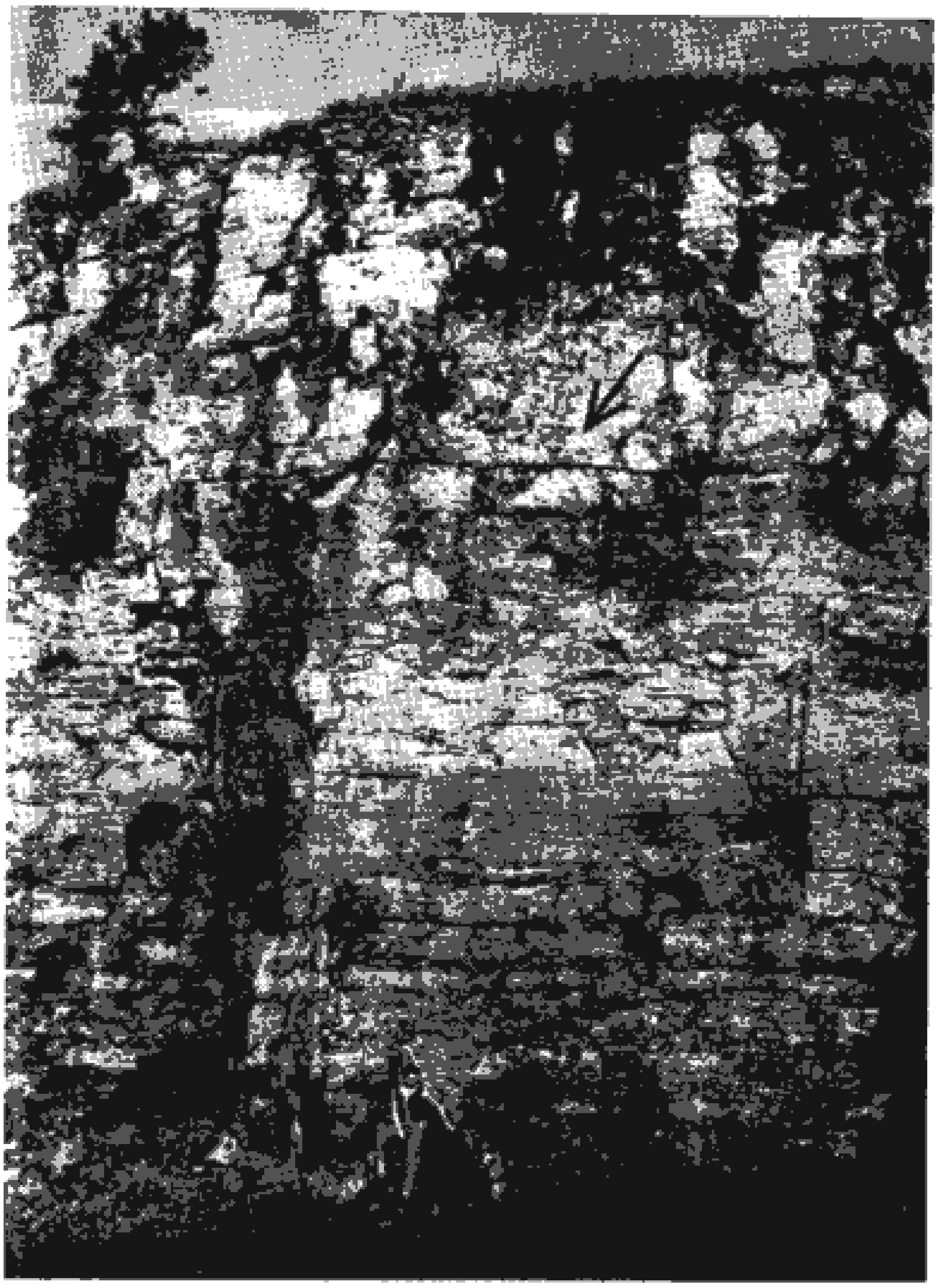
Tabulka 2. Rekurenční intervaly (periody) hlavních mimořádných událostí.

Tabulka 3. Charakteristika, původ a globální význam mimořádných událostí v Barrandienu.

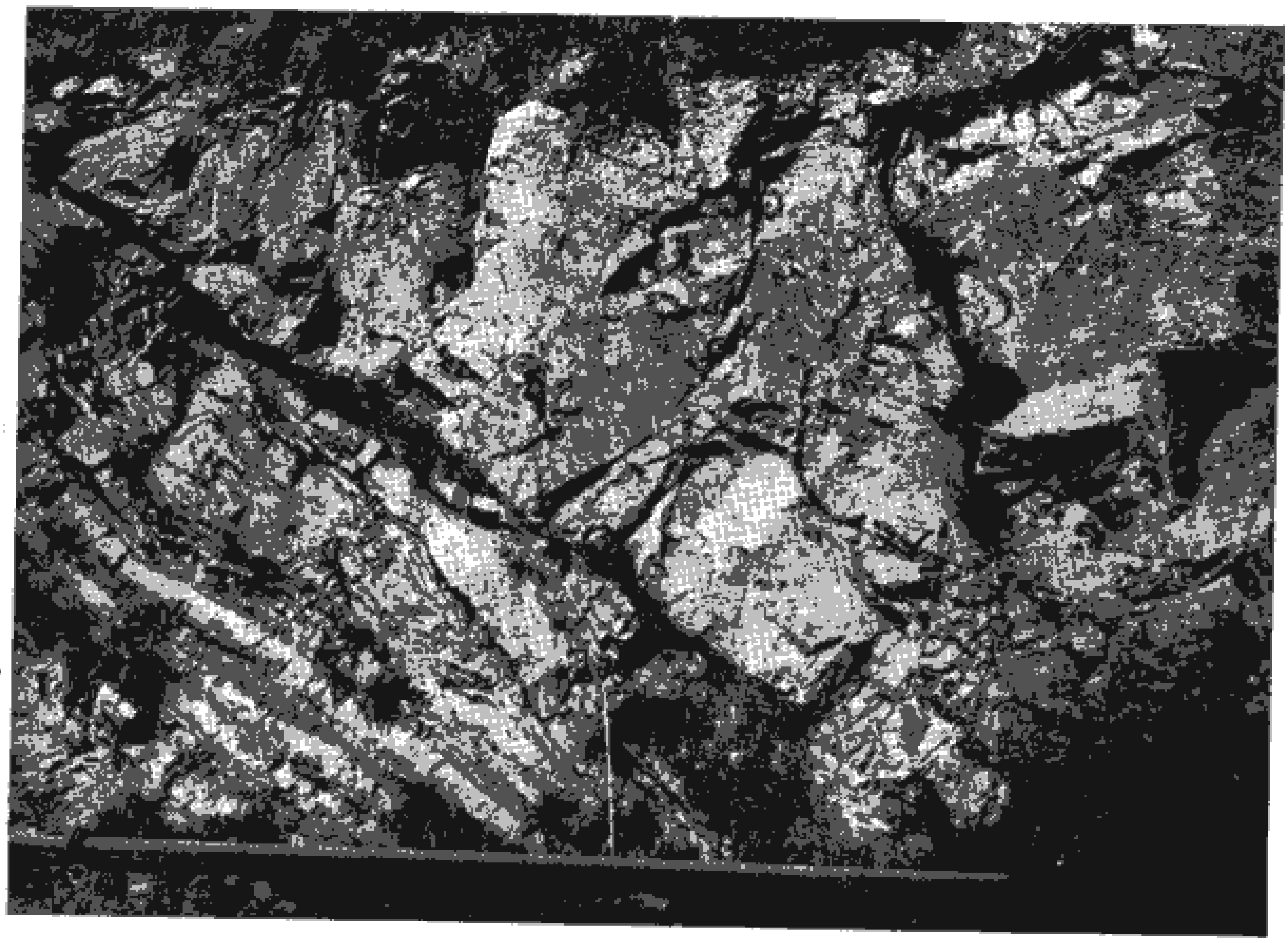
Vysvětlivky k obrázkům

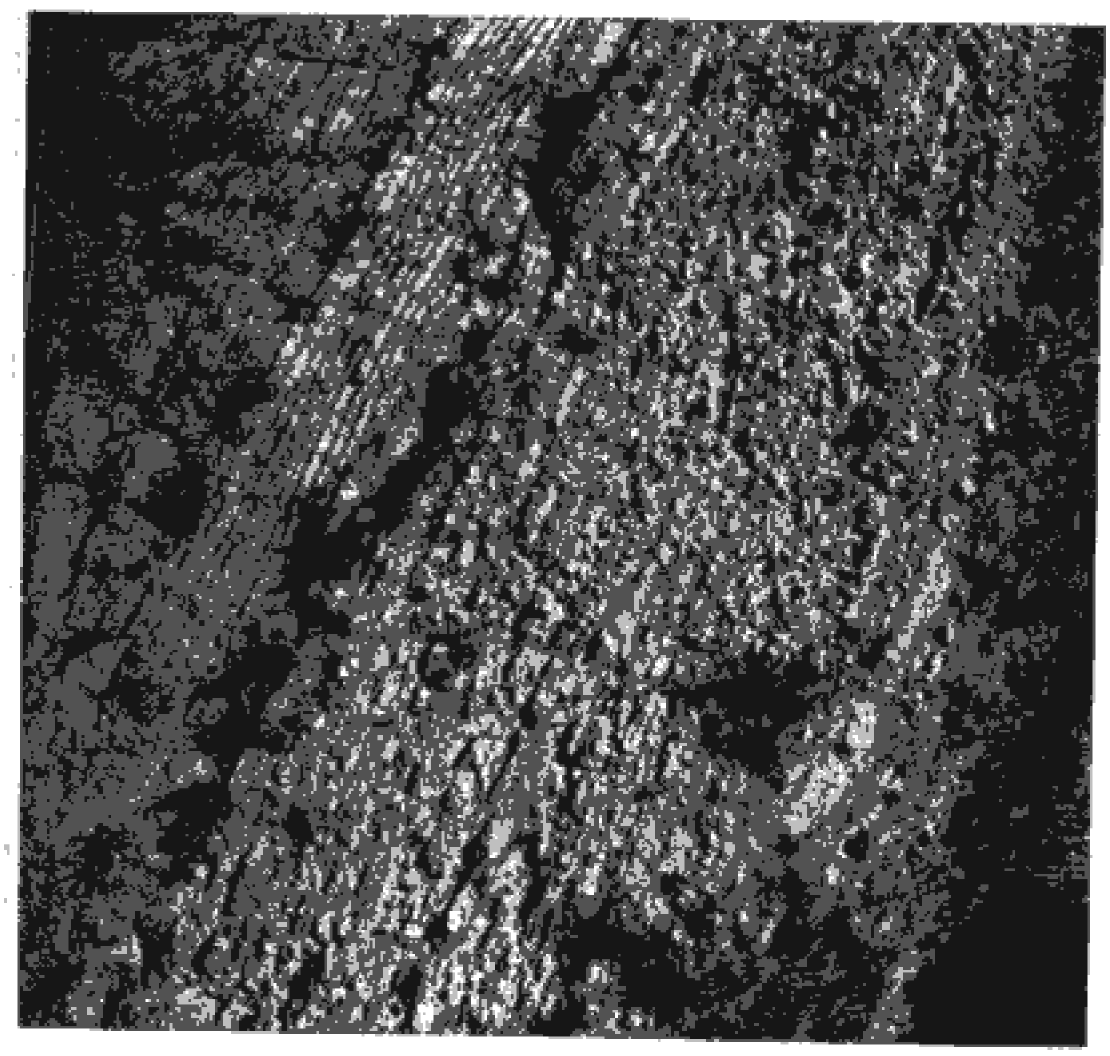
1. Stratigrafické schéma barrandienského paleozoika s vyznačenou pozicí jednotlivých událostí.
2. Vysvětlivky litologických symbolů (ke všem obrázkům).
   1 — hrubozrnné slepence; *2* — drobnozrnné slepence; *3* — pískovce; *4* — prachovce; *5* — jílovce a jílové břidlice; *6* — tmavé jílové sedimenty; *7* — sedimentární brekcie; *8* — sedimentární železné rudy; *9* — hrubozrnné biodetritické vápence; *10* — jemnozrnné biodetritické vápence; *11* — mikritové a biomikritové vápence; *12* — hlíznaté mikritové vápence; *13* — vápnité jílovce; *14* — lumachely organických zbytků; *15* — rohovce; *16* — radiolarity; *17* — fosfority; *18* — karbonátové konkrece; *19* — vulkanické produkty; *20* — stratigrafické hiáty.
3. Korelace středokambrických uloženin příbramsko-jinecké a skryjsko-týřovické oblasti (podle V. Havlíčka 1971, doplněno).
   F. — souvrství, Z. — zóna, Ass. Z. — zóna společenstva, H. — *Hydrocephalus*, P. — *Paradoxides*, E. — *Eccaparadoxides*, Bohem. — *Bohemiella*, C. — slepence.
4. Příklad vrtného profilu s projevy události ve spodním caradoku.
   Petrografické změny v hraničním intervalu letenského a vinického souvrství s vyjádřením změn zrnitosti, obsahu karbonátů, jílu a ooidů. Rudný důl v Chrustenicích, jz. od Prahy.
5. Příklady sledů s projevy události na bázi kosovu.
   Kosov u Berouna (lom na sz. svahu), Zadní Třebaň (zářez železnice), Velká Chuchle (svah na levém břehu Vltavy), Praha - Modřany (zářez silnice v Tyršově čtvrti). *x* — karbonátová vložka s hojnou bentózní faunou.
6. Tři vybrané profily se zachycenou hranicí ordovik—silur v různých částech Barrandienu (podle P. Štorcha, 1982, 1986).
   Z. — zóna, C. — *Cystograptus*, Ak. — *Akidograptus*, D. — *Demirastrites*.
7. Dva příklady profilů s projevy svrchnokopaninské (vnitroludlowské) události (podle J. Kříže a kol., 1980, 1983, doplněno).
   Hor. — obzor, *1* — vápnité a tufitické břidlice a tmavé vápence s *Cromus beaumonti*, *Diacanthaspis minuta* etc.; *2* — biodetritická lavice s *Metacalymene baylei*; *3* — vápnité břidlice s *C. beaumonti* a *Monograptus (Saetograptus) fritschi linearis* etc.; *4* — brachiopodové vápence s *Dubaria megaera*; *5* — biodetritické cefalopodové vápence; *6* — biodetritické vápence s *Dayia minor* etc.; *7* — biodetritické vápence s *Ananaspis fecunda*; *8* — biodetritické cefalopodové („ortocerové") vápence; *9* — tmavé vápence a vápnité břidlice bazálních poloh přídolského souvrství.
8. Tři příklady profilů s projevy události na hranici lochkovu a pragu.
   Kosoř - Černá rokle, lom Cikánka u Prahy - Slivence, lom na Oujezdcích u Suchomast.
9. Dva příklady profilů s projevy události na bázi zlíchovu v různých vývojích.
   Praha - Hlubočepy, zářez silnice před lomem „U kapličky"; Srbsko, zářez silnice j. od obce.
10. Tři profily s projevy dalejské události v různých faciálních vývojích.
   Praha - Klukovice (odkryv u býv. železniční zastávky), Hostim (z. od obce), Červený lom u Suchomast (areál koněpruského útesu). Ls. — vápence, N. — *Nowakia*.

1. The Basal Přídolian Event manifested by a sharp contact between massive biodetrital limestones of the uppermost parts of the Kopanina Formation, and platy, darker limestones of the Basal Přídolí Formation. Quarry at Kolednik, s. of Beroun
Photo by I. Chlupáč



2. The outcrop showing the Lochkovian-Pragian boundary. The arrow shows the onset of the Pragian fauna at the base of the Vinařice Limestone, Újezdce quarry near Vinařice
Photo ÚÚG — V. Mlýnek



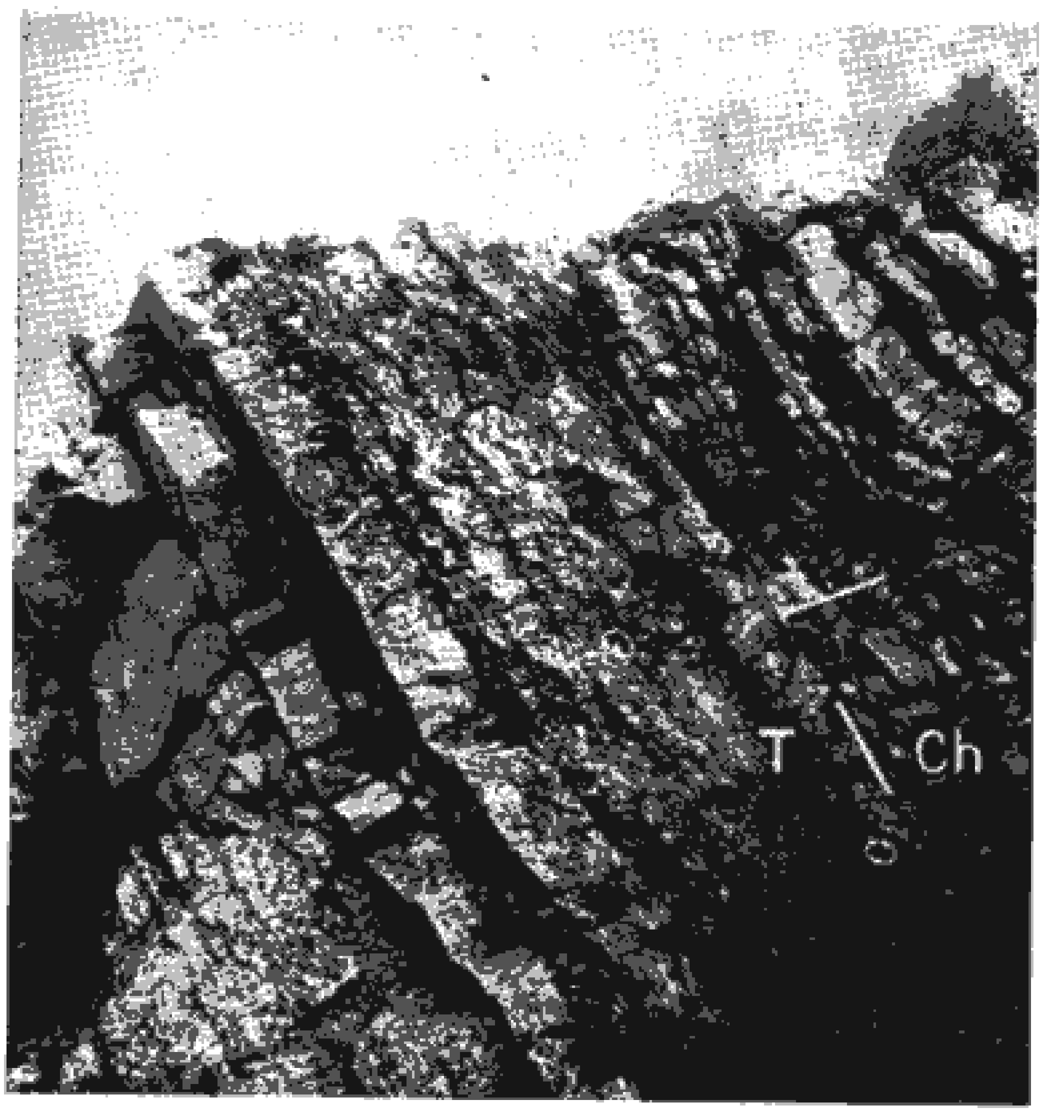


1. The Basal Zlíchovian Event demonstrated by the following succession: topmost Pragian (platy Dvorce-Prokop Limestone, on the left), overlain by the basal Zlíchov Limestone deformed by a slump structure. This layer is followed by a coarse limestone breccia. The scale is given by a one meter long rod situated just within a slump horizon. Road cut, Barrandov, Praha

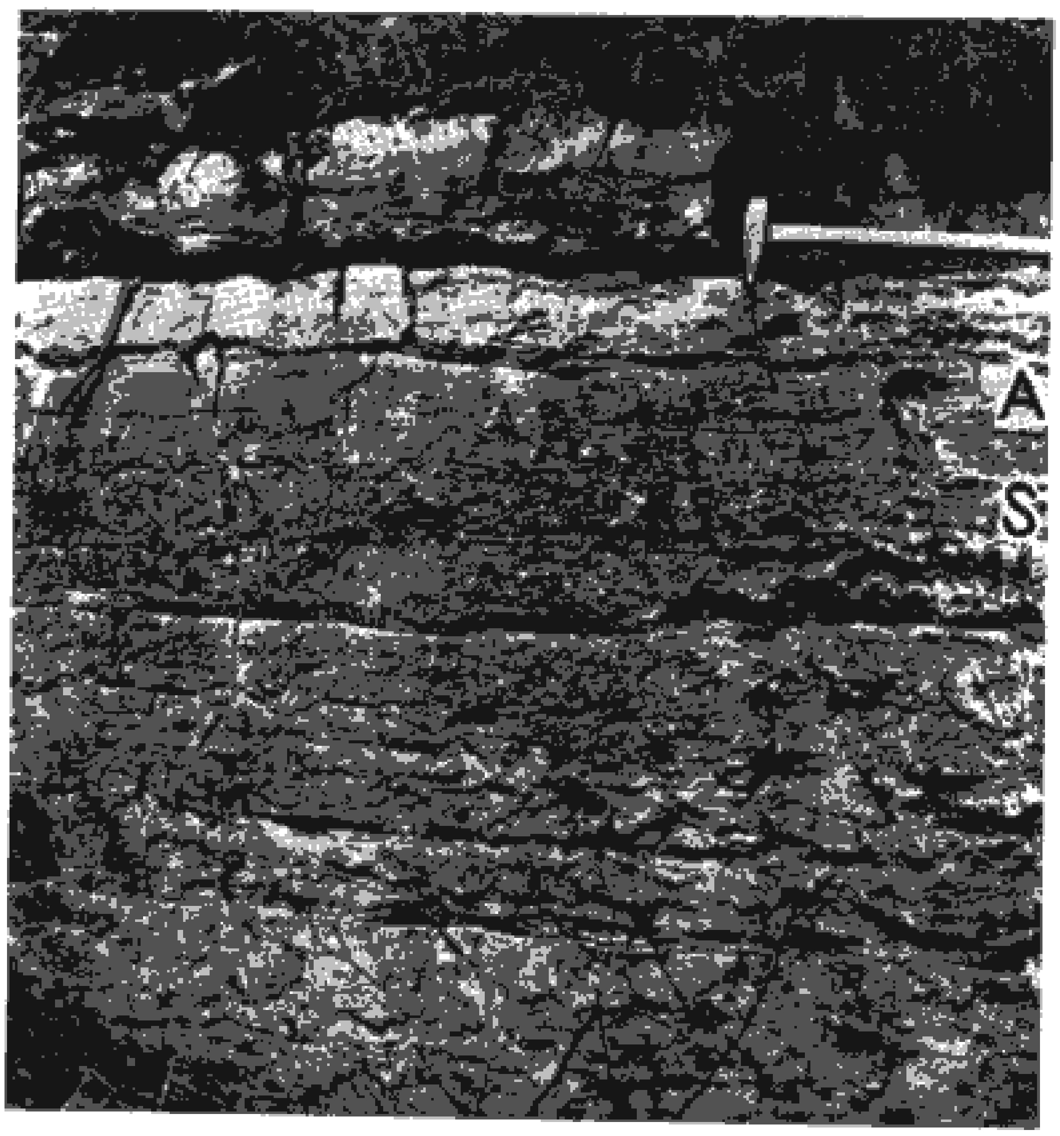
   Photo by I. Chlupáč

2. The Daleje Event demonstrated by a gradual transition from the Zlíchov Limestone into the Daleje Shale. The transition is manifested by the increase in the proportion of shale intercalations. Railway cut at Švagerka, Praha - Zlíchov

   Photo ÚÚG — B. Matoulková



1. The Basal Choteč Event: Nodular micritic Třebotov Limestone (T) overlain by platy Choteč Limestone (Ch) with thin shale interbeds. Praha - Hlubočepy
Photo by I. Chlupáč



2. The Basal Choteč Event in the Koněprusy area: Reddish biodetrital and biomicritic Suchomasty Limestone (S) overlain by light grey biosparitic Acanthopyge Limestone (A). Červený lom quarry near Suchomasty
Photo ÚÚG — B. Matoulková

The Kačák Event. The Choteč Limestone with cherts (Ch) sharply overlain by da:k clayey shales and radiolarites of the Kačák Member (K). Railway cut in Praha - Hlubočepy

Photo ÚÚG — J. Bárta

11. Tři profily s projevy události na bázi chotečského souvrství.
Praha - Holyně, lom Prastav (parastratotyp hranice mezi spodním a středním devonem), Chýnice, odkryv u býv. Jelínkova mlýna, Červený lom u Suchomast v koněpruské oblasti. Ls. — vápence, N. — *Nowakia.*

12. Projevy kačácké události ve třech vybraných profilech.
Srbsko (klasická Jahnova lokalita s. od obce), Choteč (sv. od obce u osady U Veselých), Praha - Barrandov (zářez silnice). Ls. — vápence, Mbr. — vrstvy, F. — souvrství, N. — *Nowakia.*

13. Srovnání hypotetické křivky změn mořské hladiny (podle R. A. Forteye 1984) s předpokládanými oscilacemi mořské hladiny odvozenými podle barrandienského ordoviku.

14. Křivka kolísání mořské hladiny a výskyty černých břidlic v kambriu a ordoviku Velké Británie a Barrandienu s údaji obsahu organického C v černých břidlicích a diverzity trilobitových společenstev v Barrandienu. Data z Velké Británie podle J. K. Leggetta a kol. (1981).
M.C.t. — středokambrická transgrese, T.t. — tremadocká transgrese, A.t. — arenigská transgrese, L.t. — llanvirnská transgrese, C.t. — caradocká transgrese, L.C.E. — událost ve spodním caradoku, B.K.E. — bazální kosovská událost, O.-S.B.E. — událost na hranici ordoviku a siluru, M.L.E. — vnitroludlowská (svrchnokopaninská) událost.

15. Předpokládaná křivka kolísání mořské hladiny pro devon Barrandienu. Doplněna daty o výskytu černých břidlic, průměrném obsahu nerozpustných zbytků a křivkami diverzity trilobitových společenstev (*plná čára* — druhová diverzita v hlubokovodnějších faciích, *čárkovaná čára* — druhová diverzita v mělkovodních bioklastických a útesových faciích).
L.-P.b.E. — událost na hranici lochkovu a pragu, B.Z.E. — událost na bázi zlíchovu, D.E. — dalejská událost, B.Ch.E. — bazální chotečská událost, K.E. — kačácká událost.

Vysvětlivky k přílohám

Příl. I

1. Událost na bázi přídolu, která se projevuje výraznou hranicí mezi biodetritickými vápenci nejsvrchnější části kopaninského souvrství a deskovitými, tmavšími vápenci bazálního přídolského souvrství. Lom pod Koledníkem, j. od Berouna.

Foto I. Chlupáč

2. Odkryv s hranicí mezi lochkovem a pragem. Šipka ukazuje vrstvu, kde nastupuje fauna pragu na bázi vinařických vápenců. Lom Újezdce u Vinařic.

Foto ÚÚG — V. Mlýnek

Příl. II

1. Událost na bázi zlíchovu, která se projevuje tímto sledem sedimentů: nejsvrchnější prag (deskovité dvorecko-prokopské vápence, nalevo), nad nimi bazální zlíchovské vápence deformované skluzovou texturou. V nadloží hrubozrnná vápencová brekcie. Tyč umístěná právě v skluzově deformovaném horizontu je dlouhá 1 m. Zářez staré silnice, Praha - Barrandov.

Foto I. Chlupáč

2. Dalejská událost projevující se pozvolným přechodem ze zlíchovských vápenců do dalejských břidlic. Do nadloží přibývá vložek vápnitých břidlic. Zářez železnice na Švagerce, Praha - Zlíchov.

Foto ÚÚG — B. Matoulková

Příl. III

1. Událost na bázi chotečského souvrství. Hlíznaté mikritové třebotovské vápence (T) v podloží deskovitých chotečských vápenců (Ch), které mají tenké vložky vápnitých břidlic. Praha - Hlubočepy.

Foto I. Chlupáč

2. Událost na bázi chotečského souvrství u Koněprus: červenavé biodetritické a biomikritové suchomastské vápence (S), na něž se kladou světle šedé biosparitové akantopygové vápence (A). Červený lom u Suchomast.

Foto ÚÚG — B. Matoulková

Příl. IV

Událost na bázi kačáckých vrstev: na chotečské vápence s rohovci (Ch) ostře nasedají tmavé jílové břidlice a radiolarity kačáckých vrstev (K). Zářez železnice v Praze - Hlubočepích.

Foto ÚÚG — J. Bárta

Глобальные события и стратиграфия палеозоя Баррандиена (кембрий до среднего девона, Чехословакия)

В стратиграфическом развитии палеозоя Баррандиена (средний кембрий до среднего девона) и в последовательности осадконакопления установлено несколько поворотов, несущих характер геологических событий (англ. „event"). В результате тщательного биостратиграфического и седиментологического изучения были отмечены следующие геологические события, определенные из которых носят, возможно, всемирный, глобальный характер: 1. среднекембрийские трансгрессия и регрессия; 2. тремадокская трансгрессия; 3. лланвирнская трансгрессия; 4. группа среднеордовикских трансгрессивных и регрессивных событий (лландейльский ярус до нижнего карадока); 5. нижнекарадокское трансгрессивное событие; 6. регрессивное событие на основании косовского яруса; 7. трансгрессивное событие на границе между одровиком и силуром; 8. верхнекопанинское регрессивное событие; 9. трансгрессивное событие на основании пршидольского яруса; 10. регрессивное событие на границе между лохковским и пражским ярусами; 11. событие, соответствующее базальному участку зліховского яруса; 12. далейское трансгрессивное событие; 13. трансгрессивное событие на основании хотечской свиты; 14. качацкое трансгрессивное событие.

Трансгрессивные события сопровождаются, по большей части, наступлением бескислородной среды и новых фаунистических элементов. Отдельные события характеризуются по их местному или всемирному распространению. Глобальными считаются события, приведенные под номерами 1, 2, 3, 5, 7, 10, 12, 13, 14; они объясняются эвстатическими колебаниями уровня моря, тогда как местные события вызваны, наоборот, тектоническими движениями.

Přeložil A. Kříž