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REDAKTOR JIŘI KOUŘIMSKÝ

B. BOUČEK - R. HORNÝ - I. CHLUPÁČ

SILURIAN VERSUS DEVONIAN

The Present State of the Siluro-Devonian Boundary
Problematics and Proposal of its Solution

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Introduction

The problem of positioning of the Siluro-Devonian boundary belongs to the open stratigraphical questions for more than a century. As early as in the past century it was the main point of the so-called "*Hercynian question*" the solution of which caused, namely in the 70th and 80th years, enthusiastic international scientific discussions and controversies. They revived once more during the last 15 years when the problem of positioning of the Siluro-Devonian boundary became one of the key questions of the stratigraphical geology. As the region of Central Bohemia Silurian and Devonian (the Barrandian Area) is a key terrain for solution of this matter, we want to summarize the present knowledge in order to confront it with the real situation in Bohemia. As the problems concerned with the older aspects have been already discussed before (I. Chlupáč 1953) we shall refer to the situation in 1958 when the 1st Siluro-Devonian Congress in Prague was held.

The Siluro-Devonian boundary during the Prague Congress

The Silurian of the so-called Bohemian, predominately limestone development was, according to the resolution of the Prague Congress, defined as follows: the underlying Ordovician stage was the Ashgillian and the overlying Devonian stage the Pragian. Silurian itself was then divided into Llandoveryan, Wenlockian, Budňanian and Lochkovian. The newly introduced stages Budňanian and Lochkovian have been established as there was no possibility to correlate the Bohemian development containing specific fauna with the classical areas in Great Britain and with



North Europe. The British Upper Ludlovian is lacking in graptolites and the other non-graptolite fauna is, except for isolated cases, quite different from the Bohemian one. In addition, the upper limit of the highest British Silurian (= Ludlow Series) is characterized and defined by quick facies change caused by ascending of the terrestrial (lagoon-limnic) sedimentation of Old Red type. As far as the palaeontological content is concerned the upper boundary of the British Ludlovian is, under such conditions, not sufficiently supported by index fauna and is in any case only a territorially limited facies boundary. Also the British lowest Devonian stage Downtonian is in the classical area (borders of Wales) characterized by a succession of terrigenous deposits without marine fauna and its equivalents are not definable in the limestone or other marine sections. Similar situation happened even with the lowest stage of the Rhineland facies of Devonian, the Gedinnian. In the classical area of the Ardennes the Gedinnian deposits transgress over the old folded basement affected by the Caledonian orogeny; the lower boundary is, therefore, not suitable for wide correlation. The palaeontological content of the Gedinnian in the Rhineland Area is, for facies and palaeogeographic reasons, different from that of the time equivalent sequences of the Barrandian Area.

According to the decision of the Prague Congress the Siluro-Devonian boundary was identified with the upper limit of the *Monograptus hercynicus* Zone which in the Barrandian Area agrees with the upper boundary of the Lochkov Formation, i. e. with the upper boundary of the Lochkovian stage. This conception was supported by the fact that just at this boundary a conspicuous facies change, often called the „Caledonian interval“, took place in the Barrandian Area and in some other areas (e. g. Thuringia). This change was interpreted in several ways; sometimes as a gap (J. Svoboda — F. Prantl 1953, 1955), sometimes as a relatively sharp lithofacies and biofacies change without any gap; the latter idea was supported by the presence of continuous evolutionary lines of some species and genera passing this boundary (I. Chlupáč 1957, 1960, R. Horný 1962). The main reasons supporting the positioning of the Siluro-Devonian boundary on the Bohemian stratotype were as follows: 1. The extent of the Silurian ought to be preserved equivalent to the extent of the youngest graptolite zones (the *Monograptus hercynicus* Zone is the youngest one), 2. The correlation with the classical British boundary which does not agree with the international requirements is not possible because it was not fixed in a section suitable for wide correlation. Then, the British authors themselves interpreted it during the history in several different ways. The decision of the Prague Congress was therefore not only logic, but in the existing situation it was the only decision which corresponded to the internationally admitted stratigraphic principles.

Trying to approach the British scheme as near as possible the extent of the Silurian in Bohemian sense was during the Prague Congress and even later (B. Bouček 1960, R. Horný 1960 a. o.) understood as equivalent to the British Silurian, i. e. in the original sense of B. Bouček (1934). The stages Budňanian and Lochkovian were, therefore, taken as approximately equivalent to the British Ludlovian.

Development after the Prague Congress

As the recent investigations have proved the presumption of the biostratigraphical or time equivalence of Budňanian and Lochkovian with the Ludlovian was wrong; step by step the incorrectness was revealed. The first supposition for a modern revision was a new biostratigraphical and paleontological research in Great Britain carried out by an active group known as the Ludlovian Research Group consisting of the British stratigraphers and palaeontologists (C. H. Holland, J. D. Lawson, V. G. Walmsley, J. H. McD. Whitaker and others). These authors revised carefully most of the Silurian sections in the classical regions in Great Britain, they differentiated facies and the independent stratigraphic members, and published a new stratigraphic scheme of the British Silurian together with a new analysis of fauna (C. H. Holland, J. D. Lawson, V. G. Walmsley 1959, 1963 a. o.). Delimiting the Ludlovian exactly, these papers made possible more exact parallelization of the British Silurian with the Barrandian Area for the first time. Next important step was the comparative study of the brachiopods from the Siluro-Devonian boundary beds which proved that the highest strata in the Bohemian section, still regarded as Silurian, may be equivalent to the Rhineland Gedinnian (A. J. Boucot 1960, A. J. Boucot and K. Pankiwskij 1962); this was supported also by the results of conodont research (O. H. Walliser 1962, 1964 a. o.). At the same time, G. Alberti (1963) found at the base of the Rhineland Gedinnian a new subspecies of the trilobite *Warburgella rugulosa* (ALTH) — *W. rugulosa rhenana* ALBERTI, closely related to the subspecies characterizing the base of the Lochkov Formation in the Barrandian Area (*W. rugulosa rugosa* [BOUČEK]). Next closely related subspecies *W. rugulosa maora* ALBERTI has been described from the Gedinnian (Lochkovian) of Morocco. These facts supported the approximate correlation of the base of Lochkovian with the Lower Gedinnian in Rhineland. This correlation has been finally proved by the recent discoveries of the mixed faunas of both the Rhineland and Bohemian character in Morocco (H. Hollard 1962, 1963, P. Legrand 1965 a. o.) and in Poland (H. Tomczyk 1962, L. Teller 1964 a, b). Also the French Congress in Rennes (1965) confirmed these facts. Finally, in the upper part of the Upper Graptolite Shales of Thuringia, exactly equivalent to the Lochkovian, the brachiopod *Hysterolites (H.) hysterolites* cf. *pachypleura* SOLLE was found. It gave evidence that the *Monograptus hercynicus* Zone may include even the equivalents of the Middle Siegenian of the Rhineland Lower Devonian (G. Solle 1963).

Despite the fact that the correlation of the Gedinnian and Lower Lochkovian became indisputable, the problem of the solution of the positioning of the Siluro-Devonian boundary itself was not solved. In the conceptions there appeared one main conflict: while the majority of the Western authors took Gedinnian in the classical sense (i. e. as the lowest Devonian), the Eastern authors — especially the Czech, some German, Polish and the Russian specialists — expressed strong tendencies to regard Gedinnian as the uppermost Silurian (R. Horný, H. Jaeger, L. Teller, O. I. Nikiforova, A. M. Obut a. o.) which was in conformity



even with the older aspects and tendencies (A. K. Beyer 1952, I. Chlupáč 1955). Disharmony in solving the problem became evident on the Second Siluro-Devonian Congress (Bonn, Bruxelles) in 1960 where three possibilities of positioning of the Siluro-Devonian boundary were proposed: 1. At the lower or the upper boundary of the *Saetograptus leintwardinensis* Zone (= in the middle parts of the Kopanina Formation), 2. At the top of the *Pristiograptus ultimus* Zone (= within the lower part of the Přídolí Formation), and 3. Conformably to the upper limit of the *Monograptus hercynicus* Zone (between the Přídolí and Lochkov Formations of the Bohemian sequence; the solution accepted by the Prague Congress). Simultaneously with these above mentioned possibilities, several other proposals appeared by which the situation was more or less complicated. First of all, O. I. Nikiforova and A. M. Obut came forward with a theory that in the British Silurian a gap had existed during the Lochkovian, and proposed a new name Tyras for the time equivalent of Lochkovian (synonym). A. J. Boucot (1960) and A. J. Boucot and K. Pankiwskij (1962) evaluated theoretically, without doing any new field research before, the conditions in Podolia and proposed a new name Skala for a stage which has never been defined exactly enough (no graptolite zones; it would approximately correspond to the Upper Budňanian, i. e. to the Přídolí Formation of the Bohemian sequence). On the base of rich discoveries in the deep-borings on the territory of Poland, H. and E. Tomczyk (especially H. Tomczyk 1962) tried to introduce the next theory. In spite of many new valuable data concerning the Silurian of Poland, H. Tomczyk came, namely owing to incorrect determination of certain graptolites, to wrong correlation and tectonic interpretations of the Silurian in Bohemia (the Lochkov Formation and its foreign equivalents were interpreted as possible underlying strata of the Přídolí Formation or even as a part of the Kopanina Formation). This presumption was never accepted by other authors (not even in Poland; see L. Teller 1964) and was refuted by B. Bouček and R. Horný (1964).

* Next aspects, for the first time accepted by the Czech authors, were those published by one of us (R. Horný 1962) in a compilatory work dealing with the Silurian of Bohemia. The main points were: 1. The extent of the British Ludlow in comparison with the Silurian in Bohemia is much smaller than it was presumed; it corresponds (but only approximately as far as its upper boundary is concerned) to the Kopanina Formation only; 2. The origin of the Ludlow Bone Bed and the beginning of sedimentation of the Old Red in the Ludlow Area falls into the time of sedimentation of the Přídolí Formation in the Barrandian Area; 3. During the sedimentation of the Lochkov Formation sedimentation of Old Red in Shropshire took place; the Gedinnian corresponds to certain part of the Lochkovian; 4. The Lochkovian — because of the presence of graptolites — is taken for Silurian, being equivalent to the Obere Graptolithenschiefer of Thuringia, and therefore also Gedinnian must belong to the Silurian.

These points fully proved the conclusions of H. Jaeger (1960—1962) published on the Second Siluro-Devonian Congress in Bonn and Bruxelles. H. Jaeger was the first who clearly showed that the beginning of

sedimentation of the Old Red in the classical section in Ludlow Area approximately corresponds to the base of the Přídolí Formation in the Barrandian Area. (See also H. Jaeger 1965.)

During the last few years intensive research went on in several imperfectly known regions, especially in Canada, Alaska, Siberia, Central Asia, North Africa, Australia a. o. A common feature of the majority of stratigraphical conclusions is that the Gedinnian is partly equivalent to Lochkovian, and that both stages belong to the Lower Devonian.

Nevertheless, the problems and often unimportant complications caused mainly by the neglect or negation of new literature*, still continue. As a sample we can take the joint paper of the group of authors published under the redaction of O. I. Nikiforova and A. M. Obut (1965) dealing with the Silurian of the USSR where the authors published, besides a detailed description of the stratigraphical, palaeogeographical and other conditions of the Silurian on the territory of the USSR, also a comparative correlation table. They divide the Silurian into Lower and Upper; to the Lower Silurian they arrange Llandoveryan and Wenlockian, to the Upper Silurian the Ludlovian which they divide into the Lower Ludlovian or Ludlovian sensu stricto (equivalent to the British Ludlovian) and the Upper Ludlovian which they call Tiverian. Thus, their Ludlovian sensu lato corresponds to the Bohemian stages Budňany and Lochkov. This conception differs from the stage division proposed in Prague (1958) in the point that the boundary Ludlovian s. s. / Tiverian falls into the middle parts of the Budňanian (the Tiverian stage begins at the base of the Přídolí Formation). Correlating mechanically the old Bohemian table with the British scheme, the authors received deep conflicts (especially in two different interpretations of the extent of the Ludlovian) which disagreed with the fundamental principles of the stratigraphic methods and nomenclature.

In defining the Siluro-Devonian boundary the graptolites played an important role not dependent on various often subjective aspects of different authors. Their extinction was believed to be the most precise clue for the palaeontological definition of this boundary. The main support for the identification of the upper Lochkovian boundary with the top of the Silurian sequence was their last, for a long time well known occurrence in the *Monograptus hercynicus* Zone. Since 1963, however, reports about genuine Devonian graptolites younger than the *Monograptus hercynicus* Zone have begun to appear. In spite of the fact that the stratigraphic position of the beds which yielded the graptolites was almost always not absolutely clear, these reports aroused certain doubts whether the *Monograptus hercynicus* Zone is really the youngest graptolite zone in the Earth's history.

In 1964 surprising discoveries of graptolites younger than those of the *Monograptus hercynicus* Zone have been reported from the N. Sahara. P. Planchon published as the first his communication in May, 1964. He described a new species, *Monograptus belketaiefensis* PL., from immediately above *Monograptus hercynicus*-bearing shelly beds, occurring with a faunal assemblage containing already typical Pragian elements (*Odontochile* cf. *hausmanni* [BRONGN.], *Nowakia acuaria* [RICHT.] a. o.). In 1965 (manuscript June, 1964) P. Legrand described another

* This fact is caused especially by too long time intervals between the presenting and the final edition of the papers.

new species from the beds of the same age, *Monograptus annguerensis* LEG., probably identical with the former species of Planchon.

Reviewing the biostratigraphic significance of graptolites it is very important to point out the entirely unexpected discovery in the indisputable higher Lower Devonian of the Barrandian Area realized by B. Bouček (1965) during 1965. Relatively rich graptolite fauna (at least four species) has been found in the quarry "Na stydlých vodách" near Svatý Jan pod Skalou (S of Lodenice near Beroun), in the blackish shale intercalations of platy limestones developed in the highest layers of the Dvorce-Prokop Limestone, very near to the boundary with the overlying Zlíchov Formation (Zlíchovian). As these beds belong to the uppermost Pragian, the finds of graptolites reach high up in the Emsian (the Zlíchovian is undoubtedly contemporaneous with the Upper Emsian). The most common species is here *Pristiograptus* atopus* BOUČEK, 1965. Another important species is *Monograptus cf. yukonensis* JACKSON et LENZ, similar and related without doubt to *M. yukonensis* described by D. E. Jackson and A. C. Lenz (1963) from the Road River Formation in Yukon (Canada). The age of this formation was not satisfactorily proved but the accompanying brachiopod fauna has shown much similarity to those of Gedinnian. The Road River Formation was therefore provisionally correlated with the Přídolí and Lochkov Formations of Bohemia. The close similarity of both graptolites and the presence of *Nowakia acuaria* (RICHT.) in both cases bring evidence of the Lower Emsian age of *M. yukonensis* J. et L., which occurs at a level probably slightly earlier than *M. cf. yukonensis* J. et L. in Bohemia.

The discovery of the true Devonian graptolites influenced fundamentally the idea of determining the Siluro-Devonian boundary by means of extinction of this "absolutely Silurian" group of fossils. It is necessary to search for new possibilities or solutions — the best for the world-wide correlation and, at the same time, the closest to the British conception.

Possibilities of the positioning of the Siluro-Devonian Boundary

According to the reasons discussed above, the conception of positioning of the Siluro-Devonian boundary at the top of the *Monograptus hercynicus* Zone (top of the Lochkovian) is not suitable. Its acceptance would cause, for example, hardly justifiable shifting of Dittonian and possibly even a part of Breconian of the Old Red facies (both stages with typical Devonian fauna), as well as of the Gedinnian till Middle Siegenian of the Rhineland facies, to the Silurian system. Considering the original sense and definition of the Silurian and Devonian systems in the classical regions of Great Britain and Rhineland, it would lead (except for the Bohemian development) to difficult and hardly accept-

* The provisorily generic designation follows the still used conservative classification of *Monograptidae* based on the general mode of development of the earliest thecae and shape of the mature thecae. According to the exceptionally formed sicula, we are in reality concerned with no *Pristiograptus* but a descendant of *Monograptus hercynicus* PER. The hooked thecae of *M. hercynicus* PER. have been during the phylogeny secondarily changed to tubular thecae as in the true *Pristiograptus*.

able biostratigraphical changes and to the fundamental changes of the extent of both systems. This would disagree with the general rules of stratigraphical classification.

There seem to remain only two possibilities of the positioning of the Siluro-Devonian boundary:

1. The "lowest" possibility is the British boundary, located at the top of the Whitcliffe Formation. It is really impossible to take the Ludlovian in a sense different from that defined in the Ludlow Area, i. e. including the members Elton, Bringewood, Leintwardine and Whitcliffe. The boundary with the overlying Downtonian is a typical facies boundary of no interregional value — even if we believe that there is no gap but sharp facies change, strongly influenced by gradual migration of the Caledonian folding, and therefore in various areas located in different time and biostratigraphical levels. More over, it has been well defined palaeontologically from below only; the overlying deposits contain poor fauna of paralic or limnic character which is not suitable for a correlation with the marine sequences. The exact time equivalent of this boundary has never been found anywhere in the world.

In the Barrandian Area the boundary between the Kopanina and the Přídolí Formations corresponds approximately to the above mentioned level. This conclusion is a result of a comparison of possible quickness of the evolution of fauna and of the thickness of similar deposits (limestone) in both discussed regions; common fauna is almost missing, the conodonts have not yielded enough data yet. According to the conditions in Poland (see R. Horný 1953; Teller 1964) the sedimentation of the highest layers of the Kopanina Formation passed more slowly or was even reduced; this might cause even local gaps between the Kopanina and the Přídolí Formations in the Barrandian Area. The unfortunate negative features of the British boundary fixed „by definition“ have been discussed even by the British authors (see the excellent paper by C. H. Holland 1965). According to E. I. White (1950) Murchison's historical Siluro-Devonian boundary lies several metres above the Ludlow Bone Bed and therefore the boundary fixed at the top of the Whitcliffe Formation loses its priority.

2. The second, and from our present point of view only possibility is the boundary positioned at the top of the Přídolí Formation, i. e. between the Přídolí and the Lochkov Formations (Budňanian-Lochkovian boundary). The reasons for this conception are the following:

Being uninfluenced by any sharp important facies change, the boundary is fixed absolutely reliably in a complete continuous sequence of marine deposits. It is not positioned at any sharp faunal break but within a continuous sequence of the graptolite zones and other fauna. Nevertheless, certain faunistic and facies (lithologic) changes can be observed even here.

The boundary is accompanied — at least locally — by certain and faunistic facies peculiarities, as e. g. the occurrence of the *Warburgella*-fauna, tendency to the origin of the organodetrritic limestone breccias, higher content of SiO₂, local intraformational breccias connected with the subaquatic slumps and gaps, etc. Higher import of the terrestrial components (clay minerals and silicic acid indicated by the development of hornstones) is a result of undoubted palaeogeographic changes. As was proved by B. Bouček (1964), similar changes occur in the Barrandian Area in two Devonian mesocycles: the Lower Devonian (Zlíchov Formation) and the Middle Devonian (Choteč Formation), characterizing also important palaeogeographic and faunal changes.

The highest layers of the Přídolí Formation are characterized by abundant occurrence of crinoids (the genus *Scyphocrinites* with several species, especially *S. elegans* ZENKER); accumulation of their remains usually causes the origin of layers or massive beds of crinoidal limestone. According to the possible planctonic mode of life of this crinoid, the *Scyphocrinites* Horizon is widely distributed over a very large territory. It might be found in the deposits of any warm Silurian sea more or less independently of the facies development. It is well known from the Barrandian Area, the Železné hory (E. Bohemia), the Holly Cross Mts. (Poland), Thuringia, Kellerwald, Harz, Morocco and its stratigraphical position is always proved by the assemblages of other index fauna.* The presence of the platyceratid gastropods which lived in a commensalism with *Scyphocrinites* is remarkable. The nautiloids are usually abundant in the facies of muddy bituminous limestone forming intercalations and layers of the so-called "Orthoceras"-limestone. In the muddy limestone facies occur also rich bivalves, e. g. the youngest known representatives of the typical Silurian genus *Cardiola*. Among the trilobites, the presence of the youngest known representative of *Encrinurus* is remarkable (*E. subvariolaris concomitans* PŘIBYL et VANĚK). The evolution of the widespread trilobite *Warburgella rugulosa* (ALTH) seemingly begins within the uppermost layers of the Přídolí Formation. The brachiopod assemblages is characterized here by *Septatrypa latisinuata* (BARR.) and *Dayia bohémica* BOUČEK which is an important boundary element determining the youngest Silurian deposits.

The base of the Lochkov Formation is characterized first of all by great abundance of the trilobite *Warburgella rugulosa rugosa* (BOUČEK) which occurs in rich populations just above the top of the *Scyphocrinites* Horizon. It is accompanied by the species characteristic for the Rhine-land facies at several foreign localities (*Acastella tiro* R. et E. Richter, *Treveropyge ebbae* (R. et E. RICHTER) a. o. The time continuity of these trilobites has been proved especially by the discoveries in Poland (H. Tomczyk 1962, L. Teller 1964) and in Morocco (H. Hollard 1963, G. Alberti et H. Hollard 1963). An important bivalve occurring just above the boundary is *Antipleura bohémica* BARRANDE, evolution of which we could also follow from the critically highest layers of the Přídolí Formation. Together with the macrofauna Gedinnian conodonts appear (O. H. Walliser 1962, 1964). As far as the graptolite zones are concerned, the base of the Lochkov Formation belongs to the *Monograptus uniformis* Zone; the origin of the index graptolite can be, however, ascertained in the directly underlying beds, i. e. in the highest layers of the *Scyphocrinites* Horizon. The bivalve *Hercynella* characterizes extremely rich fauna which occurs during the sedimentation of the Lochkov Formation; in the uppermost parts of the formation corresponding approximately with the Lower Siegenian first widely distributed pelagic tentaculites

* The oldest finds of typical *Scyphocrinites* accumulations occur in the lower parts of the Přídolí Formation; however, the most abundant accumulations occur in the highest layers — i. e. in the *Pristiograptus transgrediens* and *Monograptus angustidens* Zones.

(*Dacryoconarida*) occur (*Paranowakia bohémica* BOUČEK, *P. intermedia* (BARRANDE)).

The firm palaeontological determination of boundary based on widely distributed index fossils makes possible its easy recognition in the majority of the European areas. Its position stratigraphically nearer to the Ludlow Bone Bed than the boundary originally proposed (Lochkovian-Pragian) has also certain advantages for geological mapping because the correction of the existing maps will not be so drastic and will not cause such visible differences. The exact limiting of the boundary synchronous in time, will make possible a correct evaluation of the evolution of the Caledonian orogeny in the world scale, and will help to limit the territorial extent of its phases and to arrange correctly the palaeogeography of this period which is so important for the evolution of the organic world. Also C. H. Holland (1965) takes the boundary between the Budňanian and Lochkovian as the best solution of the contest and supposes that it will save a reliable synchronous limit between the Silurian and Devonian systems all over the world. Even then, he says, that "... in Bohemia the Lochkovian strata, traditionally regarded as Silurian, would become Devonian. In Britain the obvious boundary at the Ludlow Bone Bed, and the stability associated with this acceptance, would be lost." (p. 219).

Consequence of the proposed division for the Silurian in Bohemia

According to the conception proposed the Silurian of the Barrandian Area will be defined by the graptolite Zones *Akidograptus ascensus* — *Monograptus angustidens* inclusively. It will consist of the Liteň Formation (Llandoveryan and Wenlockian, the graptolite Zones *Akidograptus ascensus* — *Gothograptus nassa* incl.), the Kopanina Formation (Lower Budňanian, graptolite Zones *Pristiograptus vulgaris* — the top zone not yet defined), and the Přídolí Formation (Upper Budňanian, graptolite zones *Pristiograptus ultimus* — *Monograptus angustidens* incl.) Thus complete agreement with the original basic division of Joachim Barande appears: the Silurian sequence corresponds exactly to his "Etagé E". From the historical point of view it is useful to mention the fact that this level was conventionally proposed as the Siluro-Devonian Boundary also by E. Kayser (1878), F. Frech (1886) and B. Katzer (1888).

The proposed correction will cause certain stratigraphical changes in the Lower Paleozoic of Czechoslovakia, namely in the Železné hory, where the Silurian sequence will terminate in the dark grey *Scyphocrinites* limestone; the pure limestone in the central syncline will be of Lower Devonian age. Even the main limestone sequence of the Krásná Hora and Sedlčany syncline will become Lower Devonian; the Skoupý Conglomerate might be an equivalent of the Givetian (synchronous with the Roblín Beds of the Barrandian Area). On the Czech side of the Západní Sudety (West Sudeten) it will probably be necessary to take the volcanic series overlying the limestone sequence as Lower Devonian (Železný Brod a. o.). The idea of the Caledonian movements or even folding must be here, however, carefully revised.

A detail study of the Budňanian/Lochkovian boundary beds in the Barrandian Area will be carried out during 1966—67 and published in a special paper.

Consequence of the proposed division for the Silurian in general

In accordance with the new conception, the Silurian system will be divided into two series — the Lower and the Upper Silurian, when the lower series will consist of Llandovery and Wenlock, the upper series will correspond to the Budňany stage in Bohemia or to the Ludlovian and Lower Downtonian in Wales (or complete Downtonian in the restricted sense of J. R. L. Allen and L. B. Tarlo 1963).

It would be useful to draw attention to some unnecessary new stage names for units which have already been distinguished and limited. In 1960 (The Second Siluro-Devonian Congress, Bonn) O. I. Nikiforova and A. M. Obut introduced the name Tyras for an exact equivalent of the Lochkovian stage. This name is useless, being absolutely synonymous with the Lochkovian stage as far as the stratigraphical and even facies development are concerned. The name Lochkovian has full priority as it was established in 1958 (Ist Congress, Prague). Later (1962) these authors introduced next synonym, Tiver, and correlated it again exactly with the Lochkovian. However, in 1965 they changed their mind and correlated this stage with the Lochkovian plus Upper Budňanian (the Přídolí Formation), considering it as a substage equivalent to the "Upper Ludlovian". This process must be discussed and the sections in Central Europe and East Europe and Asia, as well as the faunal assemblages, must be carefully compared in practice.

Then, it is necessary to mention even the proposal of L. Teller (1964) to establish a new stage which he provisionally called "Postludlovian"*; it should have contained the deposits younger than Ludlovian and older than Gedinnian, i. e. the equivalents of the Bohemian Přídolí Formation (Upper Budňanian). We consider this necessity as not well-founded; it is not necessary to replace the homogenous stage Budňanian by two new independent stages. It might have certain significance in Wales where would be necessary to separate the lower, Silurian part from the Downtonian (in case that the proposal of J. R. L. Allen and L. B. H. Tarlo 1963 will not be accepted). Similarly we cannot accept the idea of A. J. Boucot (1960; et K. Pankiwsky, 1962) about the possibility of establishing a new stage Skala to cover the same "postludlovian gap". The extent of the Skala Formation is interpreted in at least three different meanings: either as complete Budňanian (O. I. Nikiforova — A. M. Obut 1960), or as the Lower Budňanian (O. I. Nikiforova — A. M. Obut 1965) or even as the Upper Budňanian (H. Jaeger 1962, 1965 a. o.). Besides, there are no graptolite zones determined in Podolia as yet; the limiting of a stage in the Silurian (even the "postludlovian") sequence without

* The „gap“ between the Ludlovian and Gedinnian in the classical table has been already commented by one of us (B. Bouček 1963) as „Postludlowium“ (theoretic name).

graptolites seems to be rather illusory. There is no doubt that for the graptolite or limestone facies of the highest Silurian and lowest Devonian the division proposed and accepted at the Prague Congress in 1958 (Budňanian, Lochkovian) is fully satisfactory.

Consequence of the proposed positioning of the Siluro-Devonian boundary for the stage division of the Lower Devonian

The present proposal of the Siluro-Devonian boundary makes possible to leave the stage Gedinnian, designated in the Rhineland facies, in the Lower Devonian. In the region of Ardennes where the Gedinnian was established by Dumont 1848, the base of this stage cannot be, however, regarded as suitable stratotype for the Siluro-Devonian boundary (see above). The Downtonian, defined in the region of the Old Red facies, will be the boundary stage, the lower part of which will belong to the Silurian, the upper part to the Devonian. If the proposal of J. R. L. Allen and L. B. H. Tarlo is accepted, the Siluro-Devonian boundary will lie between the Downtonian and the Dittonian (see the table). In any case, the boundary will be generally nearer to the boundary proposed by J. R. L. Allen and L. B. H. Tarlo 1963. The lower boundary of the Downtonian is a clear sharp facies boundary (a "bad boundary") of no use for wider correlation (see J. R. L. Allen and L. B. H. Tarlo 1963, L. B. H. Tarlo 1964 a. o.). As far as the classical regions are concerned, the stratotype can be chosen in the Central Bohemia section, the continuous sequence of which, well exposed and developed in pure marine facies, satisfies all internationally admitted demands for limiting of the boundaries between the systems.

From the point of view of the evolution of fauna, the proposed positioning of the Siluro-Devonian boundary between the stages Budňanian and Lochkovian has many advantages even when the disadvantages cannot be undervalued. A great advantage is that the so-called Rhineland heterogeneous complex of the Lower Devonian fauna, so specific for the special conditions influenced by the Caledonian movements, will remain in the Lower Devonian (it is characterized namely by specific spiriferids, abundant bivalves (*Grammysia*, *Modiomorpha*), homalonotid and asteropygid trilobites, corals (*Pleurodictyum*) a. o.). The proposed correction is useful even from the point of view of the phylogeny and development of the primitive fish because the widely distributed index genus *Pteraspis* with the closely related genera which make possible the zonal division of the postdowntonian deposits of the Old Red type (see e. g. E. I. White 1950, 1956, W. Schmidt 1959, 1960) will belong to the Lower Devonian. Next great advantage for example is that in the stage Lochkovian wide evolution of the pelagic tentaculites (*Dacryocornarida*) begins which makes possible a detailed zonal division of the Lower Devonian in Bohemian facies, with the possibility of extremely wide and reliable correlation (see B. Bouček 1964). The main disadvantage is in the fact that the development of graptolites passes the proposed boundary till the Lower Devonian; therefore, these valuable Silurian index fossils will lose the importance for determining the Si-

luro-Devonian boundary by means of their extinction. On the other hand, however, the zonal division of the highest Silurian and the Lower Devonian based on the graptolites makes possible an extremely accurate limiting of the boundary as well as its wide application. The occurrence of the graptolites together with the cosmopolitan and widely-occurring pelagic tentaculites (*Dacryoconarida*) is highly important and useful. Another "disadvantage" is, that there exist relatively small differences between some groups of the Upper Budňanian and Lower Lochkovian fauna (e. g. in the proetid, cheirurid and the odontopleurid trilobites, eurypterids etc.); this is, however, quite natural in the continuous succession without distinct facies changes.

As it is generally well known, the Lower Devonian in Rhineland facies is divided into three stages: Gedinnian (A. Dumont 1848), Siegenian and Emsian (H. Durlodot 1900). These stages are, however, objectively limitable in the Rhineland faies only, i. e. in the predominately terrigenous psammitic development distributed in the regions affected by specific palaeogeographic conditions and is far from being the most widespread type. In the much more widely distributed Bohemian facies characterized by carbonate deposits and specific thermophilic fauna, fundamentally different from the Rhineland one, the stage division proposed by the Prague Congress (1958) proves fully competent. According to the correction proposed, the lowest Devonian stage will be the Lochkovian, followed by the Pragian and the Zlíchovian. Certain advantage is that in both the Rhineland and Bohemian facies the tripartite division of the Lower Devonian will be obtained. However, this division will not be equivalent. Individual stages of both magnafacies have different time volume: the Lochkovian is not equivalent to Gedinnian — its stratigraphic volume is wider (it includes even the lower part of Siegenian of the Rhineland division). The Pragian stage corresponds to higher Siegenian and Lower Emsian, while the Zlíchovian is relatively exactly equated with the Upper Emsian. This has been confirmed by the decisions of both the Prague (1958) and the Bonn-Bruxelles (1960) Congresses. Important line lying practically at the same level in both the Bohemian and Rhineland facies is only the Lower/Middle Devonian boundary defined by the base of the Lower Eifelian *Gyroceratites gracilis* Zone (i. e. between the Zlíčov Formation and the Daleje Shales or their equivalents in the Barrandian Area).

It is necessary to notice that the differences between the stage division of the Rhineland and Bohemian Devonian are not given conventionally, "by definition", but with regard to the objective differences of the palaeogeographic and facies conditions. These differences influenced the character of the faunas so intensively that unification of the division of both sequences would be neither possible nor useful in the present state of research as it would veil the characteristic features of both magnafacies. This state is a quite natural reflection of complicated palaeogeographic and therefore even palaeobiogeographic conditions, in the Lower Devonian after the early Caledonian orogenic processes. Gradual disappearance of the differences between the Rhineland and Bohemian development which begins since the Upper Emsian leads, on

the contrary, to the possibility of accepting one common stage division into the Eifelian and Givetian for both regions (see I. Chlupáč 1959, H. K. Erben 1962).

Conclusions

Thank to the progress of the recent geological and palaeontological investigations based on wide international cooperation, the solution of the Siluro-Devonian boundary problem has been finally solved. The internationally accepted solutions, however, will influence even the stratigraphical schemes in the classical areas accepted for a considerably long time. The newly proposed corrections will help to the traditional practice in Great Britain by means of drawing the boundary only slightly higher than at the top of the Ludlovian. Nevertheless, the lower boundary of the Downtonian defined by the Ludlow Bone Bed will not be the stratotype of the Siluro-Devonian boundary. The proposed correction will make possible to leave the Gedinnian, traditionally regarded as Devonian, within the Lower Devonian and therefore to preserve the tripartite division of the Lower Devonian developed in the Rhineland facies. In the Bohemian facies the Siluro-Devonian boundary must be shifted downwards; the Lochkovian will be of Lower Devonian age. Being defined on the stratotype in the excellently exposed marine sequences in the Barrandian Area, the Siluro-Devonian boundary would be widely correlatable.

New finds of the graptolites in indisputably Devonian strata (Emsian) have shown that the evolution of graptolites continued even longer into the Devonian. The occurrence of graptolites cannot be, therefore, regarded as the main criterion of a Silurian age. Similarly the facies of the black graptolite shales is not restricted to the Silurian sequence only. As a sample we can take the development of Lochkovian in Thuringia (Obere Graptolithenschiefer) or the development of the Lower Lochkovian (the *Monograptus uniformis* Zone) discovered by one of us (B. BOUČEK) in Yugoslavia in 1965. On the other hand it is a great success that we shall be able to correlate precisely the limestone (Bohemian) development and stages with the West European sequences and finally to unify the different conceptions of the Siluro-Devonian boundary.

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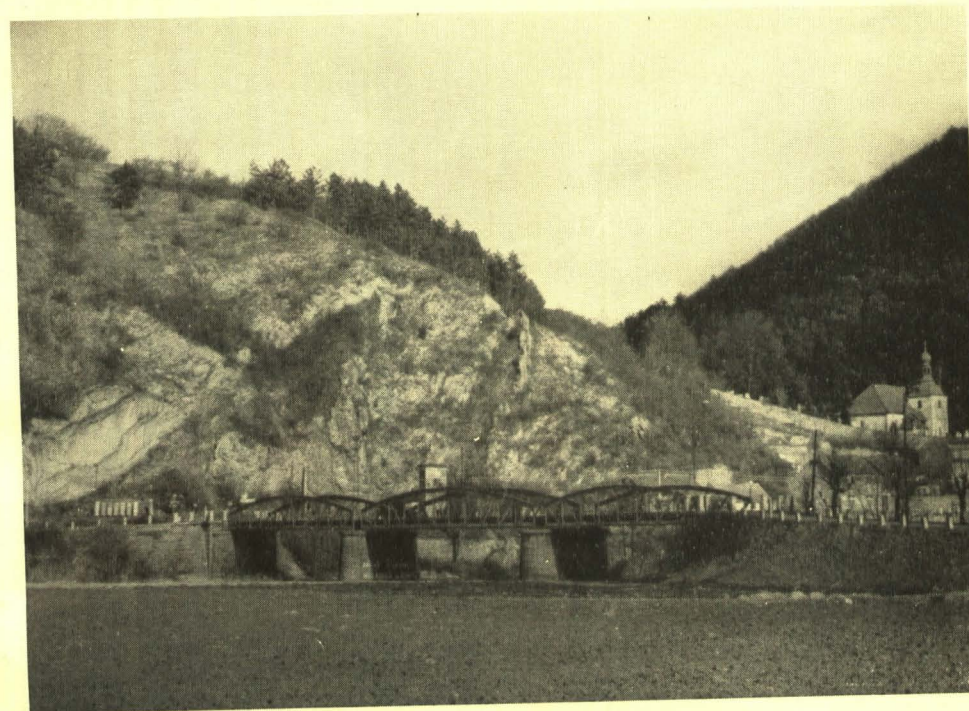
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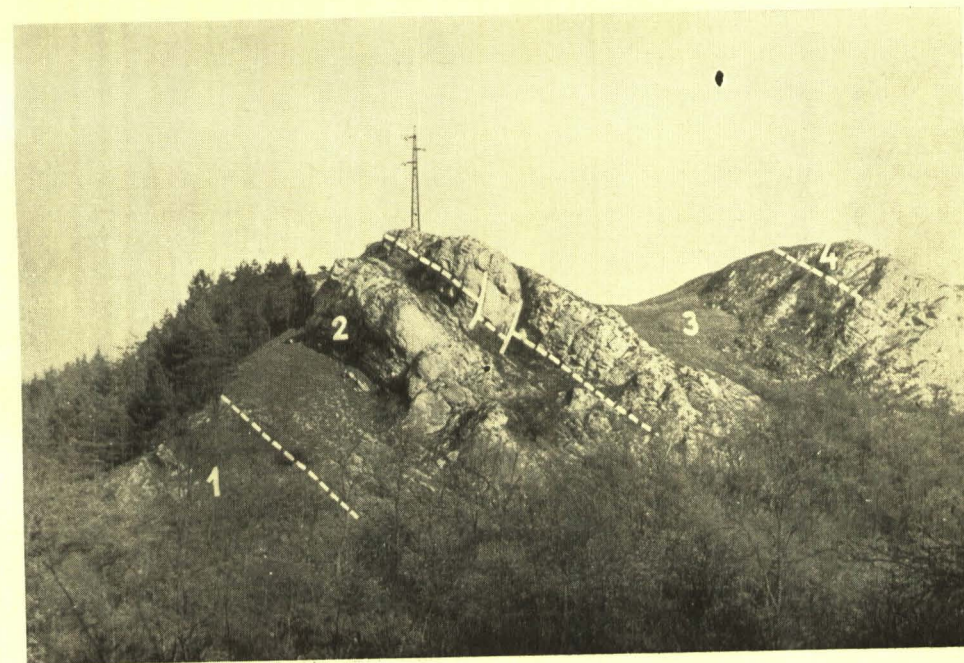
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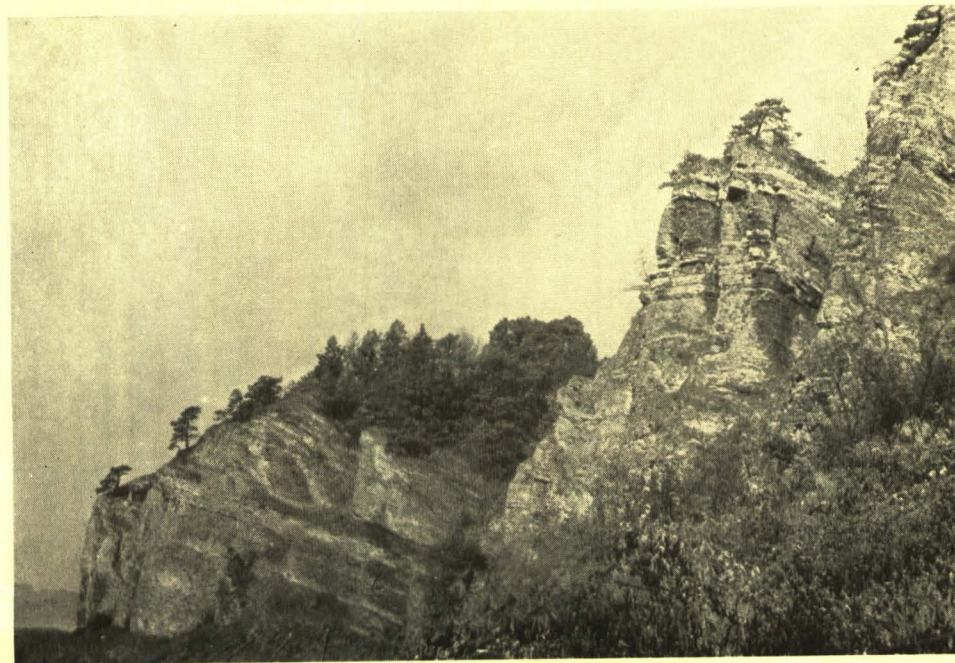
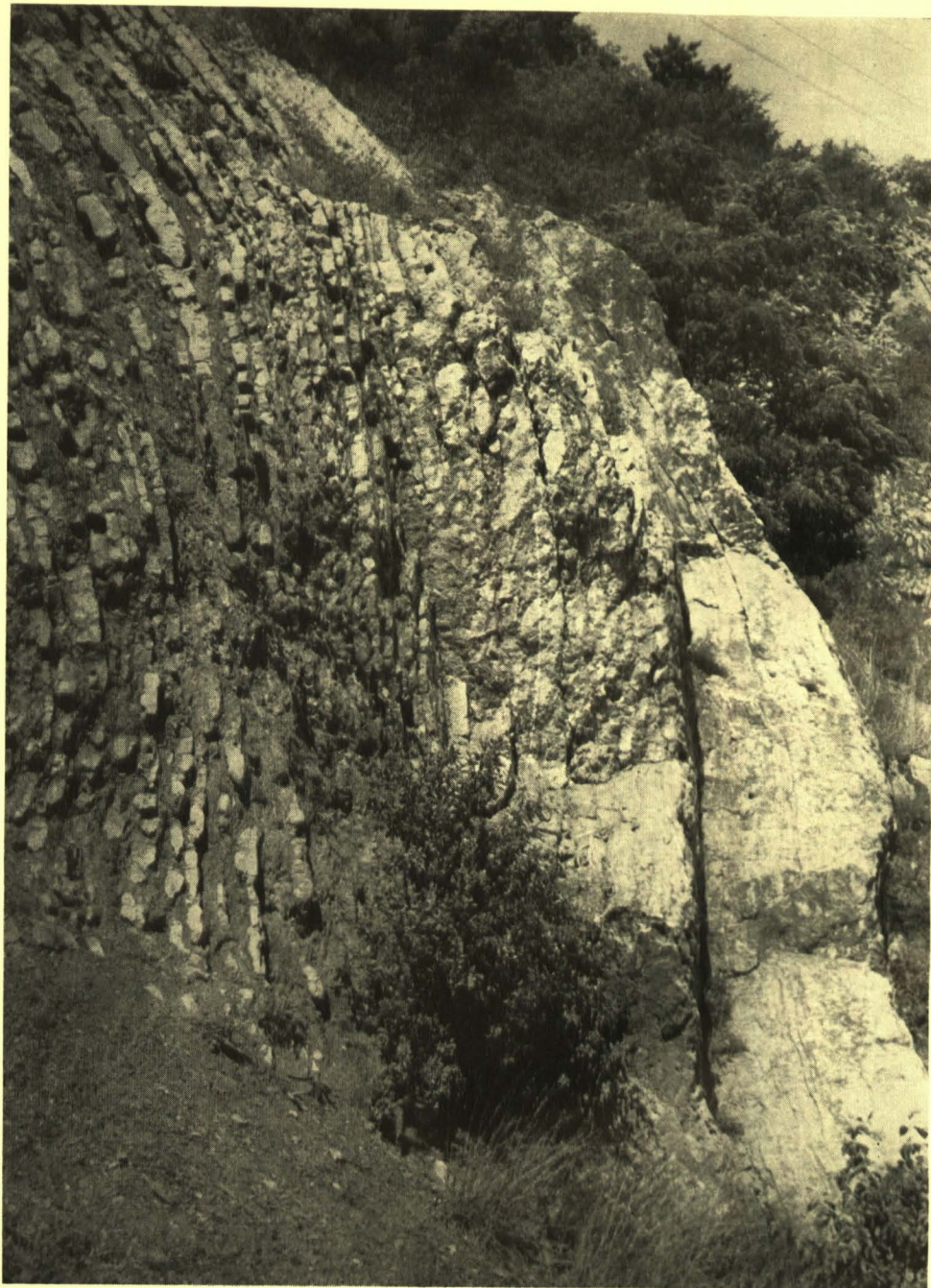
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EXPLANATION OF PLATES

I.

1. The Budňany Rock near Karlštejn. Boundary beds between the Přídolí nad the Lochkov Formations. The massive folded M-shaped bank belongs to the *Scyphocrinites* Horizon. (Photo R. Horný).
2. Nová Ves near Jinonice SW of Prague. Well exposed section through the Upper Silurian (1 — Kopanina Formation, 2 — Přídolí Formation) and the Lower Devonian (3 — Lochkov Formation, 4 — Slivenec Limestone). (Photo R. Horný).

II.

1. The Budňany Rock near Karlštejn. Detail of the highest parts of the Přídolí Formation showing platy limestones with intercalations of shales containing limestone concretions (left) and massive cephalopod and crinoidal limestone (the *Scyphocrinites* Horizon). (Photo R. Horný).

III.

1. Čertovy schody near Koněprusy. High layers of the Lochkov Formation corresponding to the Lower and Middle Siegenian. (Photo R. Horný).
2. The Radotín valley, „near the poplars“. Boundary beds between the Přídolí and the Lochkov Formations. 1 — platy limestones with intercalations of shales, 2 — basal parts of the *Scyphocrinites* Horizon, 3 — the *Scyphocrinites* Horizon, 4 — platy limestone of the Lochkov Formation. (Photo R. Horný).

IV.

1. The quarry „Na stydlých vodách“ near Svatý Jan pod Skalou. Lower Devonian, uppermost Pragian (Dvorce-Prokop Limestone). Detail of the figure 2. The muddy limestones layer between the two massive banks of nodular limestone contains intercalations of the graptolite-bearing shales (*P. atopus* BOUČEK etc.). (Photo B. Bouček 1965).
2. The quarry „Na stydlých vodách“ near Svatý Jan pod Skalou. The locality of the Devonian graptolites indicated by X. The wall in the right side of the photograph belongs to the lower part of the Zlíchov Formation (Lower Zlíchovian, = Upper Emsian). (Photo J. Svoboda 1965).

SBORNÍK NÁRODNÍHO MUZEA V PRAZE

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REDAKTOR JIŘÍ KOUŘIMSKÝ

VLADIMÍR BOUŠKA

GEOLOGIE A STRATIGRAFIE VLTAVÍNOVÝCH NALEZIŠŤ V ČECHÁCH A NA MORAVĚ

ÚVOD

Vltavíny se vyskytují v jihozápadní části Československa ve dvou ne zcela spolu souvisejících oblastech — v jižních Čechách a na jihozápadní Moravě.

V jižních Čechách pokrývají naleziště vltavínů zhruba oblast svrchně křídových a třetihorních pánví budějovické a třeboňské. Pouze aluviálními náplavy dnešních řek byly vltavíny ojediněle rozneseny dále na sever, Vltavou k Podolsku a Červené nad Vltavou, do oblasti Týna nad Vltavou (Neznášov a Bohunice), Lužnicí byly zaneseny k Soběslavi a starou Nežárkou k Veselí nad Lužnicí. Údaj J. J. Jahna (1899) o nálezu vltavínů v pleistocenních pyropových štěrcích v severních Čechách je velice sporný. I přes intenzivní těžbu pyropů v uvedené oblasti a důkladný průzkum se neuskutečnil ani jeden další nález (R. Rost, 1962).

Zatím nejjižnějším nalezištěm v jižních Čechách je lokalita Besednice. Západním směrem omezuje zhruba výskyt moldavitů linie Zlatá Koruna, Ratiborova Lhota u Lhenic, Třebanice a Vodňany, východní hranicí jsou Jindřichův Hradec, Třeboň a Lipnice. Vltavíny se nacházejí téměř v celé rozloze vymezené oblasti s výjimkou rudolfovské hrástě, pruhu krystalických hornin mezi budějovickou a třeboňskou pánví, a krystalinika zabíhajícího do zmíněné oblasti od severu. Jsou to však jen zatím údaje. Rozsah vltavínových nalezišť bude jistě větší zejména v jižnějších a západních částech jižních Čech, jak ukazují některé výskyt štěrků, které jsou typickým sedimentem, v němž se vltavíny ponejvíce vyskytují. Také uvnitř uvedené oblasti musíme počítat s novými nalezišti, protože rozšíření průvodních sedimentů je značného rozsahu. Zejména třeboňská pánev je po této stránce méně prozkoumána.

Doménou moravských nalezišť je Třebíč. Tam nejzápadnějším výskytem jsou obce Kojetice a Řípov, západně od Třebíče a naleziště dále pokračují dvěma směry: