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Perunica microcontinent in the Ordovician (its position within the Mediterranean Province, series division, benthic and pelagic associations)

Mikrokontinent Perunika v ordoviku (jeho postavení v rámci mediteránní provincie, revize oddělení, bentická a pelagická společenstva)

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Abstract: Perunica, involving major part of the Bohemian Massif, is assumed here as a separate microplate between the Gondwanan and North European (Baltic) cratons; it gradually moved from high southern latitudes in the Lower Cambrian across the palaeoequator to the low northern latitudes in the Upper Palaeozoic. All Ordovician series present natural units and reflect the main geological events such as the tectono-eustatic and glacio-eustatic movements. The Dobrotivá (about Llandeilo) and Beroun (about Caradoc) are epochs of maximum provinciality whereas the Kralodvor and Kosov are poor in endemic brachiopod and trilobite genera. The Tornquist's Sea functioned as an effective barrier only in the middle Ordovician whereas it did not prohibit faunal migrations between Perunica and Baltica in the Tremadoc, Kralodvor and Kosov. Changes in faunal associations reflect not only the changes in the positions of the plates and microplates (i.e. Baltica, Gondwana, Armorica, Perunica, and Avalonia) but also the climatic gradients; the circumpolar sphere (Gondwana) has yielded much less diversified benthic fauna than other regions of the world.

Lists of brachiopod and trilobite genera have been compiled to serve as reliable bases for palaeogeographic considerations.

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As follows from projects of the Subcommission on Ordovician stratigraphy, the most important tasks are to unify the global chronostratigraphy, revise the Series divisions, and propose the boundary stratotypes for each Series; in the future, the project will be extended to compile the global maps of facies, biogeography, and palaeoceanography. The aim of the present paper is to contribute to the Subcommission projects in the following ways: 1. Are the Series used in Bohemia natural units reflecting the main geological events? 2. Can the Bohemian units be used also outside Bohemia? 3. What is the relation of the Bohemian Massif to other regions of the Mediterranean Province?

Our study is based on the Bohemian Massif where the Prague Basin has yielded a complete Ordovician sequence without gaps in its central part, unmetamorphosed sections weakly disturbed by folding and faulting and usually bearing many benthic and pelagic biotas. Owing to these features, the Bohemian Ordovician was a subject of many biostratigraphic, lithostratigraphic, sedimentologic, and palaeontologic studies (review of earlier

papers: Havlíček-Vaněk 1966), recently supplemented by revision of benthic and pelagic communities and study of climatic fluctuations (Havlíček 1982, 1989; Havlíček-Vaněk 1990). Further, possible global events in the Prague Basin were revised by Chlupáč and Kukal (1988).

We are fully aware that several difficulties may arise when trying to apply the Bohemian scale to those of West Europe, North Africa, and elsewhere. Before doing so, we would like to draw attention to position of the Bohemian Massif within the Mediterranean Province and to its relation to other continents and microcontinents such as Gondwana, Baltica, and Armorica. Our results are based on analyses of brachiopod and trilobite associations of Europe and North Africa. We have also taken full use of palaeomagnetic data available from Bohemia (Krs et al. 1986, 1987) and Armorica (Perroud 1985; Perroud, Van der Voo - Bonhommet 1984).

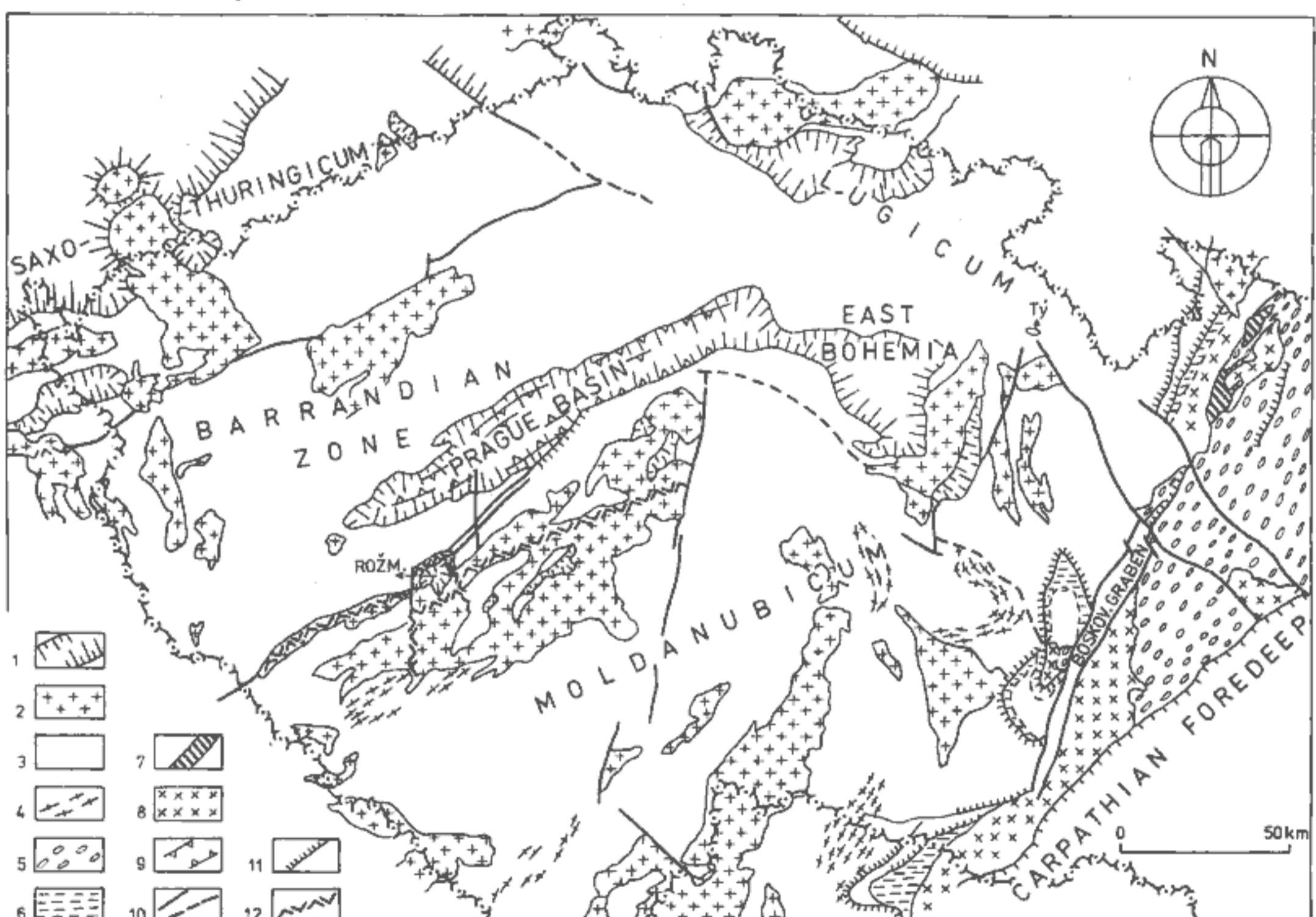
We came to the conclusion that the major part of the Bohemian Massif forms a separate microplate comparable in its significance to Armorica and called here Perunica;

the minor (i.e. the eastern) part of the Bohemian Massif should be assigned to the Brunovistulicum which is a coherent part of the East European continent (Suk 1979). Further, we have tried to better characterize each of the Ordovician series in its facies development, benthic and pelagic associations, climatic fluctuations, eustatic movements, and to compare the "Bohemian" development to those of other regions of the Mediterranean Province.

The Mediterranean (=*Selenopeltis*) Province proved to be a mosaic of various terranes often largely differing from each other in rates of subsidence, presence or absence of gaps, and various possibilities of faunal migrations. From the tectonic point of view, the Mediterranean Province involves several pericratonic and epicratonic basins and linear sedimentary depressions that were confined to the Armorican and Perunican microcontinents and to the northern part of Gondwana. The northern and eastern boundaries of the Mediterranean Province coincide with supposed sutures of the former Rheic and Tornquist's Seas; unfortunately, the discovery of these sutures is often difficult because of subsequent (Variscan) tectonic processes. Moreover, the Rheic and

Tornquist's Seas, in coaction with climatic gradients, did not function as migration barriers throughout the whole Ordovician; the maximum provinciality was established in the Middle Ordovician (Dobrotivá and Beroun Series), whereas the barriers faded away during the Upper Ordovician (Kralodvor, Kosov) after a reduction of the Rheic and Tornquist's Seas. The northern boundary of the Mediterranean province was probably not constant during the Ordovician; for example, the Sambre-Meuse region in Belgium (south of the Caledonian Brabant Massif) was a component of the Mediterranean Province because it has yielded solely the characteristic, Bohemian-type trilobites, hyolithids, and bivalves in the (lower) Beroun (Sart-Bernard Formation; Maillieux 1939), whereas the same region became part of the North European Province in the Ashgill with a prevalence of Baltic-type brachiopods and trilobites (Sheehan 1988; Lespérance & Sheehan 1988). It is then clear that the origin, evolution and final reduction of the Rheic Sea are intricate problems which need a further investigation.

For palaeogeographic reconstruction of the Mediterranean Province, we have used all available data



1. Position of the Prague Basin within the Bohemian Massif (simplified geological map).

- 1 - Ordovician;
 - 2 - Variscan plutonics;
 - 3 - pre-Ordovician (mostly pre-Palaeozoic) rocks;
 - 4 - possible Lower Palaeozoic rocks in the "Varied Complex" of the Moldanubian Zone;
 - 5 - Devonian and Carboniferous sequence of the Moravo-Silesian Basin;
 - 6 - possible Lower Palaeozoic sequences in the Moravian and Silesian Units;
 - 7 - Variscan amphibolites (north Moravia);
 - 8 - crystalline fundament of the Brunovistulicum;
 - 9 - synsedimentary faults and flexures;
 - 10 - main faults;
 - 11 - overthrusts, nappes;
 - 12 - main fault zones used as intrusion ways by the Variscan granitoids.
- Rožm. - Ordovician in the Rožmitál Graben; Tý - Ordovician near Týniště nad Orlicí (East Bohemia).

concerning the benthic and pelagic biotas. In analysing the brachiopod and trilobite associations, each plate (microplate) was considered as a natural unit comprising a suite of shallow to deeper-water environments in various Ordovician sequences. The brachiopods and trilobites of uncertain stratigraphic provenience and doubtful systematic position were omitted in lists of fossils.

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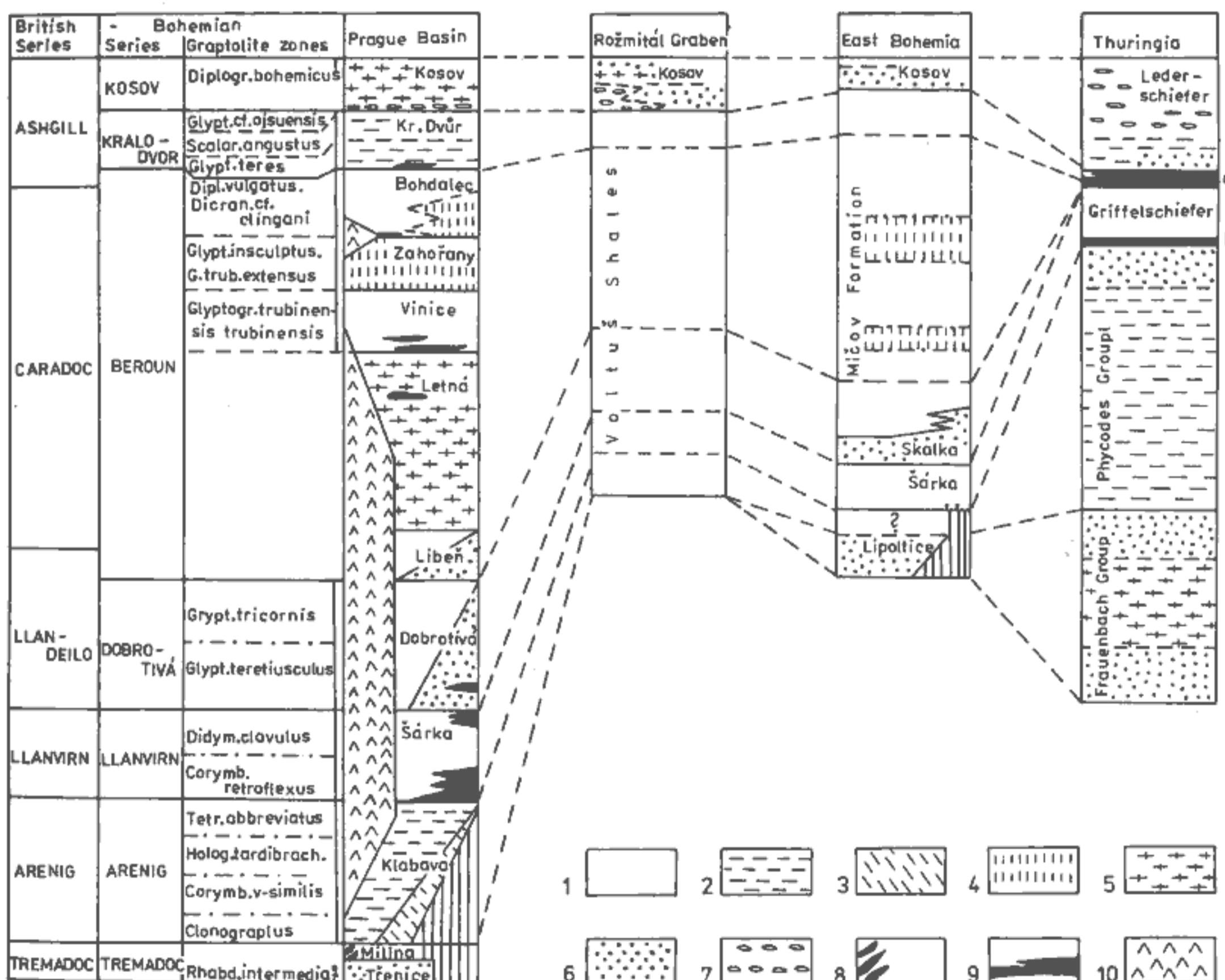
Perunica microcontinent

The Variscan orogeny of western and central Europe is often explained by means of the plate tectonics theory

based on study of ophiolite complexes, high-pressure metamorphics, convergent plate-margin volcanism, palaeomagnetic data, possible climatic changes, and distribution of assemblages of invertebrates (survey of basic data: Patočka 1989).

Significant components of the mobile Variscan belt are the Bohemian Massif, Armorican and Central Massifs in France, Iberian Peninsula, and a suite of minor blocks, all assumed as fragments of the original Gondwanan supercontinent.

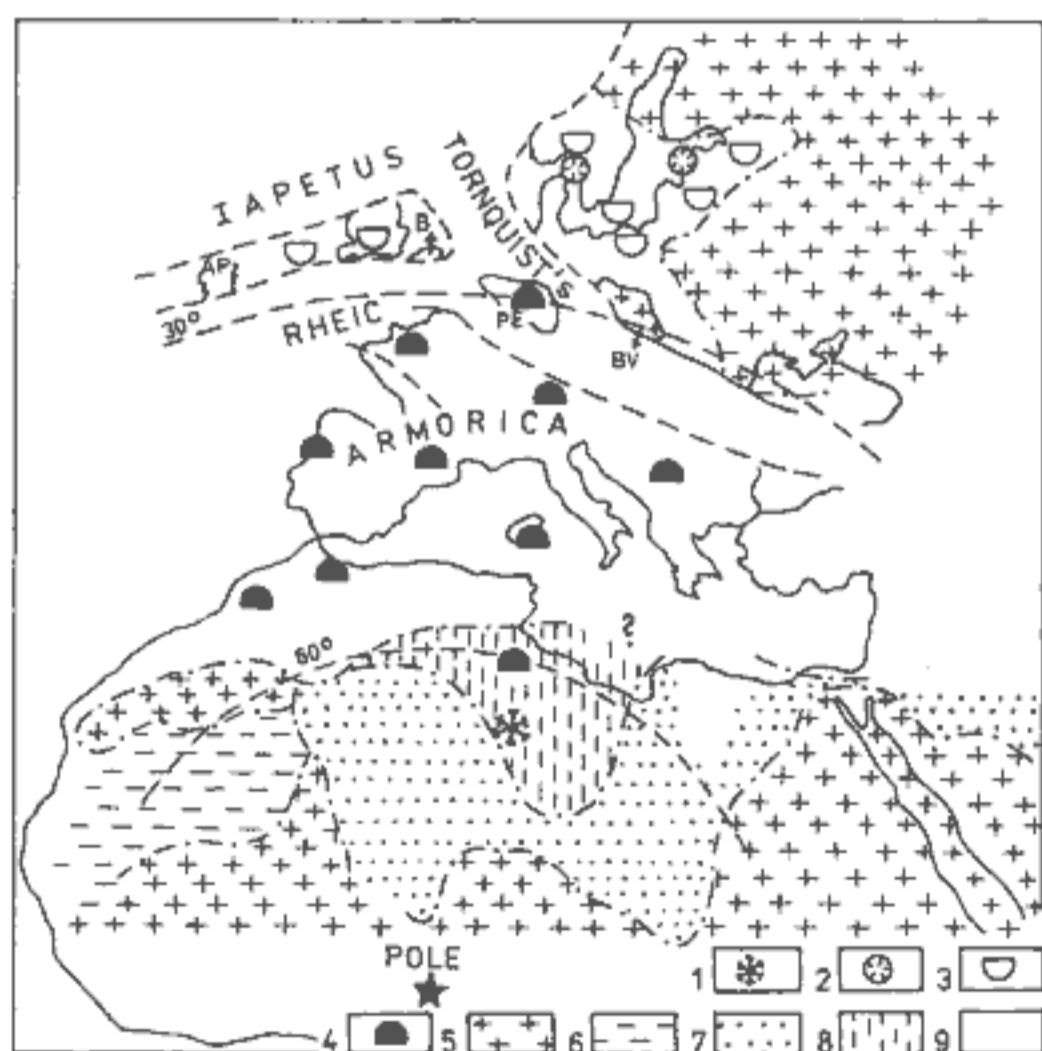
According to Suk (1979), Dudek (1980), and Suk et al. (1984), the Brno Unit (Brunovistulicum) of the eastern margin of the Bohemian Massif is a part of the Cadomian shield of Fennosarmatia (North European continent) as it follows from the radiometric data (660-550 mil. years, less commonly 1270 mil. years; Dudek & Šmejkal 1968; Dudek & Melková 1975; Míšař et al. 1983), metamorphic development of crystalline rocks quite different from those of the Variscides but rather close to those of the



2. Correlation of main Ordovician sequences in Perunica.

1 - mostly black shales; 2 - greenish shales and siltstones; 3 - red sediments; 4 - siltstones; 5 - alternation of sandstones and shales; 6 - sandstones, quartzites; 7 - diamictites, presence of drop-stones; 8 - sedimentary cherts; 9 - sedimentary iron ores; 10 - pyroclastics.

Fennosarmatian shield (Tomšík 1972; Cháb & Suk 1976), and interpretation of geophysical data. According to Weiss (1977), the Brunovistulicum extends to the Boskovice Furrow and even farther westwards under the overlying Moravian Unit (Moravicum). For this reason, the present-day Bohemian Massif is assumed as a composite unit involving both the Gondwanan and the Fennosarmatian elements. The major part of the Bohemian Massif, involving the Moldanubian, Barrandian and Saxothuringian (Saxothuringian-Lugian) Zones, constituted during the Lower Palaeozoic a separate microplate, comparable in its significance to Armorica. For the palaeogeographic purposes, it is called here Perunica (after Perun; in the early Middle Ages, Perun was adored as God of thunder by Slavic tribes). Perunica extends northwards to the Hercynian (Mid-European) suture that originated by closure of the Rheic (Mid-European) Sea and now presents the boundary between the Saxothuringicum and Rhenohercynicum in the Variscan orogeny (Burrett-Griffiths 1977; van Breemen et al. 1982). The Ordovician sediments of the former Rheic Sea most probably underlie the Devonian rocks of the Rhenohercynicum as shown by the presence of predominantly clayey-shale sequences bearing graptolites, pelagic trilobites of cyclopygid biofacies, blind deep-water trilobite *Dionide* in association with other rare organisms (e.g. Llanvirn-Caradoc sequence).



3. Reconstruction of the Mediterranean Province in the Upper Ordovician (about Beroun Series); Scotto-Appalachian Zone (Laurentia) omitted.
1 - evidence of glaciation; 2 - reef bodies; 3 - distribution of Sowerbyella;
4 - distribution of Aegiromena; 5 - pre-Palaeozoic shields; 6 - regression
of the Sea in the Beroun; 7 - marine and fluviomarine sandstones, mainly
Tigillites Community; 8 - "Lingulid" domain; 9 - marine sediments
dominated with Aegiromena-Drabovia fauna; further assemblages of the
Anglo-Welsh and Baltic type faunas. AP - Avalonian Peninsula; B -
Brabant Massif; BV - Brunovistulicum; PE - Perunica.

Ebbe-Sattel, Sauerland; May 1989; Koch, Lemke & Braukmann 1990). In the east, the tectonic contact between Perunica and the Brunovistulicum (including the Moravian and Silesian Units) is associated with significant overthrusts and nappes with a pronounced eastern vergency, for the first time recognized by Suess (1912). The pre-Devonian sediments of unknown original extent and thickness, deposited in the basin between Perunica and the Brunovistulicum, were mostly destroyed during the pre-Devonian collision of these blocks; the sequence of mica-schists, quartzites, graphite mica-schists with interlayers of black metalydites, crystalline limestones, and basaltic lavas of the Velké Vrbno and Branná Groups (Hrubý Jeseník Mts.), was assigned by Květoň (1951) to the Ordovician and Silurian without any palaeontologic evidence. The same age was postulated for the closely similar complexes of the Svatka and Olešnice Domes (Moravian Unit) by Zoubek (1946) and Svoboda and Zoubek (1950), but age of these rocks still remains questionable owing to absence of fossils; Misař et al. (1983) and Suk et al. (1984) placed them to the pre-Cambrian.

Perunica has many features in common with Armorica as the two were incorporated into the Variscan orogen between the Gondwanan and North European (Baltic) continents. Perunica, presenting a separate block or microcontinent, drifted from high latitudes in the southern hemisphere across the palaeoequator to the low northern latitudes in the latest Palaeozoic as follows from data obtained from Bohemia by Krs et al. (1986, 1987): early Middle Cambrian greywacke, Příbram-Jince Basin - about 39° S; Upper Cambrian andesite, same basin - about 29° S; Lower Ordovician silicite and tuffitic rock, Prague Basin - around 28° S; Lower Devonian micritic limestone, Prague Basin - roughly between 5 and 9° S; platform sediments in Northern Bohemia, Upper Carboniferous - around palaeoequator; Permian - between 6 and 10° N; Triassic - between 14 and 18° N.

A similar behaviour has been found in Armorica; according to Perroud and Bonhommet (1981), Perroud, Van der Voo and Bonhommet (1984) and Perroud (1985), Armorica drifted from high latitudes in the southern hemisphere (60-70° in the Ordovician) toward the North European continent.

A rather independent development of Perunica may be deduced from its probable rotation as shown by changes in palaeomagnetic directions from about 65° in the Middle Cambrian, through 90° in the Upper Cambrian, to 126.65-131.84° in the Lower Ordovician (Krs et al. 1986, 1987). These data support the idea of Burrett (1983) who, after reinterpreting the apparent polar wander path, suggested that the Bohemian Massif had moved independently from Armorica during the early Palaeozoic.

The present-day shape of Perunica does not correspond to the original state in the Cambrian and Ordovician because of a considerable reduction of the former basins

as shown by discoveries of significant overthrusts and nappes in the Saxothuringian-Lugian Zone (Oberc 1980; Behr et al. 1980; Behr 1983; Weber - Behr 1983). Extent of supposed Lower Palaeozoic rocks in the Moldanubian Zone is still beyond reasonable considerations in spite of records of "Silurian" microfossils (acritarchs, chitinozoans) in deeply metamorphosed sequences (Andrusov & Černá 1976, Konzalová 1980). The present authors suspect that majority of these "palynomorphs" are no true microfossils and thus are not applicable for biostratigraphic purposes. In any case, the Moldanubian complex involves the deeply metamorphosed Lower Palaeozoic rocks as shown by discovery of spores at Rittsteig in Bavaria (Pflug & Reitz 1987; Reitz 1987). For this reason, the original Zoubek's idea (1946, 1948) that the Ordovician and Silurian elements are included in the Moldanubian complex, seems to be correct (e.g. some sequences within the "Varied Complex").

Perunica involved several narrow basins of graben or rift origin seated deep in the pre-Cambrian fundament. In the Ordovician, the clastic sequences have yielded richly diversified benthic assemblages in the Prague Basin (Havlíček & Vaněk 1966; Havlíček 1982) but poor associations in East Bohemia (Havlíček & Šnajdr 1951), Thuringia (Freyberg 1923), Taunus Mts. in Hessen (Struve 1975) and other areas. These assemblages are in some respects similar to those of Armorica and the Tindouf Basin of the African part of Gondwana, all assigned to the cold-water Mediterranean Zoo-geographical province. The Mediterranean fauna, however, is not uniform over the whole province owing to latitudinal-climate control, depth control, facies development, and various rates and modes of migration of individual animal groups (Havlíček 1989). Although the Ordovician assemblages of Armorica and Perunica have several features in common (e.g. elements of the *Aegiromena-Drabovia* fauna in the Upper Ordovician), they differ from each other in many ways. Babin et al. (1976) pointed to a certain degree of provincialism in shallow-water sediments and recorded abundant Bohemian elements only in the southern part of the Armorican Massif, whereas the Bohemian influence was weak in other "synclines". We may conclude that some kind of a barrier (a deeper sea between Armorica and Perunica?) prevented an easy exchange of benthic invertebrates between the Prague Basin of Bohemia and the separate faunal domains of Armorica.

Judging from the facies development, composition of faunal assemblages, and palaeomagnetic data (Perroud & Bonhommet 1981; Perroud, Van der Voo & Bonhommet 1984), Armorica was a coherent part of Gondwana in the Ordovician. This idea is supported by the occurrence of "typical" Gondwanan elements *Paterorthis* (Carinthia, Austria) and *Protomendacella* (Montagne Noire) in shallow-water epicontinental seas of Armorica but never reaching Perunica. On the other hand, some brachiopods

abundant in the Gondwanan Tindouf Basin (e.g. *Tissintia*, *Tafilatia*) inhabited the shelves of both Armorica and Perunica.

By contrast to Armorica, the microcontinent of Perunica was situated close to Baltica in the Cambrian and lowermost Ordovician (Tremadoc) because of a great similarity in the sessile and vagrant benthos. During the Arenig, however, the interchange of invertebrates between Baltica and Perunica became weak and finally, it stopped in the Dobrotivá and Beroun being replaced by invasion of many Armorican and Avalonian elements. At the same time, the faunal interchange between the Tindouf Basin (Gondwana) and the Prague Basin (Perunica) increased considerably. We must be aware, however, that the migration of invertebrates was controlled not only by the relation of Perunica to the neighbouring continents, but also by climatic changes and surface currents in seas of that time.

Palaeogeographic reconstruction of the Mediterranean Province is an intricate problem. The sea separating the Armorican and Perunican microcontinents from the North European continent (Baltica) was often explained as a several thousands of kilometres broad ocean called the Mid-European Sea (Whittington & Hughes 1972; Neuman 1976; Burrett & Griffiths 1977; Perroud, Van der Voo & Bonhommet 1984) or the Tornquist's Sea (Cocks & Fortey 1982; Neuman 1984, 1988; McKerrow 1988; Fortey & Cocks 1988). Moreover, a moderately to considerably broad Rheic Sea was often assumed to have occurred between Armorica and Avalonia (Cocks & Fortey 1982; 1988; McKerrow & Cocks 1986; Fortey & Cocks 1988). On the other hand, Havlíček (1989) believed that the main factor leading to the pronounced provincialism in the Ordovician was not the presence of extensive oceans but the latitudinal-climate control. He emphasized that each significant climatic change was succeeded by a mass-migration of benthic fauna across the sea, thus indicating that the Rheic and Tornquist's Seas were no serious barriers against faunal interchange (e.g. in the Kralodvor and Kosov). Our analysis of brachiopod and trilobite assemblages has shown that the Rheic and Tornquist's Seas, together with temperature gradients and surface currents, acted as true barriers against faunal migration mainly in the middle Ordovician (e.g. in the Dobrotivá and lower-middle Beroun).

Due to spreading and subsequent closing of the Rheic and Tornquist's Seas, the position of Perunica within the Mediterranean Province was gradually changing. This process induced significant changes in benthic assemblages; for example, the Baltic elements were numerous in the Bohemian Tremadoc but absent in the Dobrotivá and lower-middle Beroun. Avalonian affinity in Perunica reached its maximum in the lower Llanvirn but after this peak it decreased considerably. The most easy interchange of invertebrates between Perunica and Gondwana was confined to the Beroun; the marked

invasion of warmer-water Avalonian-type benthic fauna has been recorded in the upper Beroun and lower Kralodvor in Armorica but not in Perunica; a sudden appearance of the Hirnantia fauna and its distribution over many regions of the World in various climatic belts indicates a disappearance of all barriers against faunal migration in the uppermost Ordovician (Kosov).

Tremadoc

The Tremadoc Series usually begins with an extensive transgression accompanied by the early Tremadoc, pandemic distribution of the "Dictyonema Shales" bearing staurograptid and rhabdinoporal nematophorous dendroid graptolites that appeared after the burst of the "rooted dendroids" of the uppermost Cambrian age. The Tremadoc terminates with a world-wide Ceratopyge regressive event and a disappearance of all bithecae-bearing dendroids (anisograptids) (Erdtmann 1986, 1988). Owing to the lack of graptolites in the Mediterranean Province, the biostratigraphy of the Tremadoc is based mainly on the sessile and vagile benthos. The earliest Tremadoc is marked by an appearance of the clitambonitid and poramborthid brachiopods. In the Iberian Chains (North-East Spain), the earliest clitambonitid genus *Protambonites* co-existed with the index "Upper Cambrian" brachiopod *Billingsella* which survived there into the lowermost Tremadoc (upper part of the Valconchán Formation; Havlíček & Josopait 1972). Among trilobites, the earliest "typically Ordovician" families appear for the first time in the Tremadoc (e.g. *Asaphidae*, *Homalonotidae*, *Cheiruridae*, *Harpidae*, *Nileidae*, *Dalmanitidae*, *Calymenidae*).

In the Mediterranean province, the successive lower Ordovician transgression is clearly documented both in Armorica and Perunica where the Lower Ordovician beds rest with a weak to pronounced unconformity on the Cambrian or even pre-Cambrian rocks. Less commonly, the lower Tremadoc beds are underlain by the Upper Cambrian regressive sequence with possible gaps in its sedimentation (Montagne Noire; Hammann et al. 1982); in Celtiberia, a continuous clastic sequence contains the passage beds between the Upper Cambrian and Lower

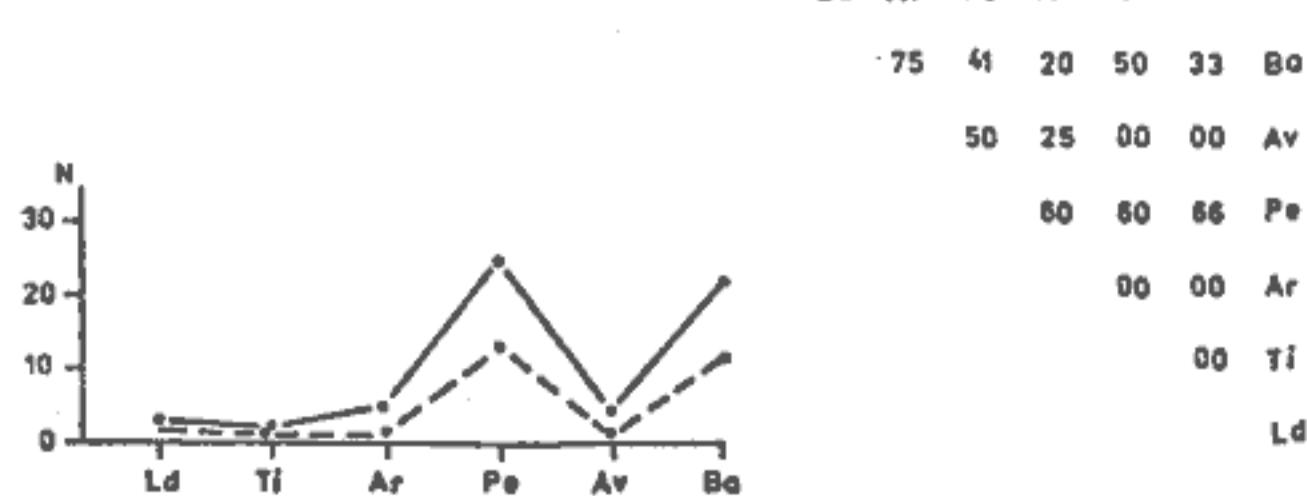
Tremadoc (Valconchán Formation) in which the lowermost Tremadoc has yielded an index echinoderm *Oryctoconus*, Pacific-type trilobites *Pagodia* (*Wittekindtia*) and *Chuangia*, and Mediterranean-type brachiopods *Poramborthis* and *Protambonites* (Wolf 1980; Havlíček & Josopait 1972).

Also in Perunica, the lower-middle Tremadoc strata usually overlie the Precambrian bedrock or the Lower and Middle Cambrian formations after an Upper Cambrian dry-land period. A continuous Upper Cambrian-Lower Ordovician sequence may be present in some areas of the Saxothuringian-Lugian Zone but always is obscured by tectonic and metamorphic processes. In the core of Perunica, the Prague Basin is highly sensitive to reflect all the sea-level fluctuations during the Ordovician; the Ceratopyge regressive event coincides there with the regressive Mílina Formation (upper Tremadoc); its mostly lagoonal character is apparent from a prevalence of chemical sediments formed as beds of cherts that represent more than 50 per cent of the total thickness of the formation. Consequently, the benthic fauna is low-diversified and consists mainly of small inarticulate brachiopods and spicules of sponges (*Leptembolon* Community); other shelly fauna and trilobites (all often fragmentary) are confined only to two small areas in the Prague Basin (Olešná-Kváň and Úvaly).

Our palaeogeographic considerations are based mainly on the study of invertebrates; the benthic assemblages, however, are far from being uniform over the whole Mediterranean Province because of enormous distances between the Gondwanan epicratonic basins and the Avalonian, Armorican, and Perunican terranes. In the Tremadoc, the benthic communities were subjected both to the latitudinal-climate control and various types of living conditions in shallow-water subtidal, intertidal, or even fluviomarine environments (Havlíček 1989); deeper-water sediments (intercalations of "Dictyonema Shales") are an exception in the Tremadoc of the Mediterranean province (e.g. at Břežany, Prague Basin).

The cold-water benthic communities of the Tremadoc age are confined to the circumpolar sphere (North Africa) and are very distinct from those of Armorica and Perunica in that they are dominated by the Tigillites Community (e.g. intertidal and shallow subtidal sandstones, Ajers

4. Brachiopod assemblages in the Tremadoc. To the left: graphs showing decreasing number of genera from the warm-temperature zone toward the circumpolar sphere. Solid line - total number of genera in each region investigated; dashed line - number of endemic genera in each region investigated. To the right: coefficients of association between 6 regions investigated. N - number of genera; Ar - Armorica; Av - West Avalonia; Ba - Baltica; Ld - Gondwana ("Lingulid" domain); Pe - Perunica; Ti - Gondwana (Tindouf Basin).



Formation, Hoggar Mts.; Ash Shabiat Formation, Murzúq Basin, Libya; sequence of "Grès à Skolithos", Mauritania) (Beuf et al., 1971; Legrand, Poueyto & Rouaix 1959; Collomb 1962; Havlíček 1989). The "Lingulid domain" (Sanhar Formation; Massa, Havlíček & Bonnefous 1977), recovered in the extremely shallow-water Ghadamis Bassin (Tunisia, Libya), is another type of a pronouncedly cold-water environment.

By contrast to Gondwana, Perunica occurred in a temperature zone not far from Baltica. For this reason, many Baltic warmer-water elements could colonize the Prague Basin, East Bohemia, and Bavaria in the lower and upper Tremadoc.

A serious interregional correlation based on brachiopods is rather difficult as many have so far been found only in the Tremadoc rocks of Bohemia (almost a third of genera discovered in the Prague Basin). If we exclude these endemic genera, the rest of brachiopods involves typically Baltic elements such as *Thysanotos*, *Leptembolon*, *Schmidtites*, *Broeggeria*, *Lacunites*, and *Eosiphonotreta*, whereas the West European (Spanish) brachiopods are much less frequent (*Protambonites*, *Poramborthis*). Migration of shelly fauna between Perunica and the peri-Gondwanan basins was next to zero owing to considerable temperature gradients.

The trilobites give a more reliable picture of faunal migrations, because only *Kaufmannia* (Bavaria) and *Eulomina* and *Holoubkovia* (Prague Basin) may be regarded as endemic in Perunica. The Baltic elements constitute about 34 per cent of trilobite genera in the Tremadoc of Perunica. The Baltic affinity is most apparent in central Bohemia where the Prague Basin contains about 50 per cent of trilobite genera of Scandinavian origin.

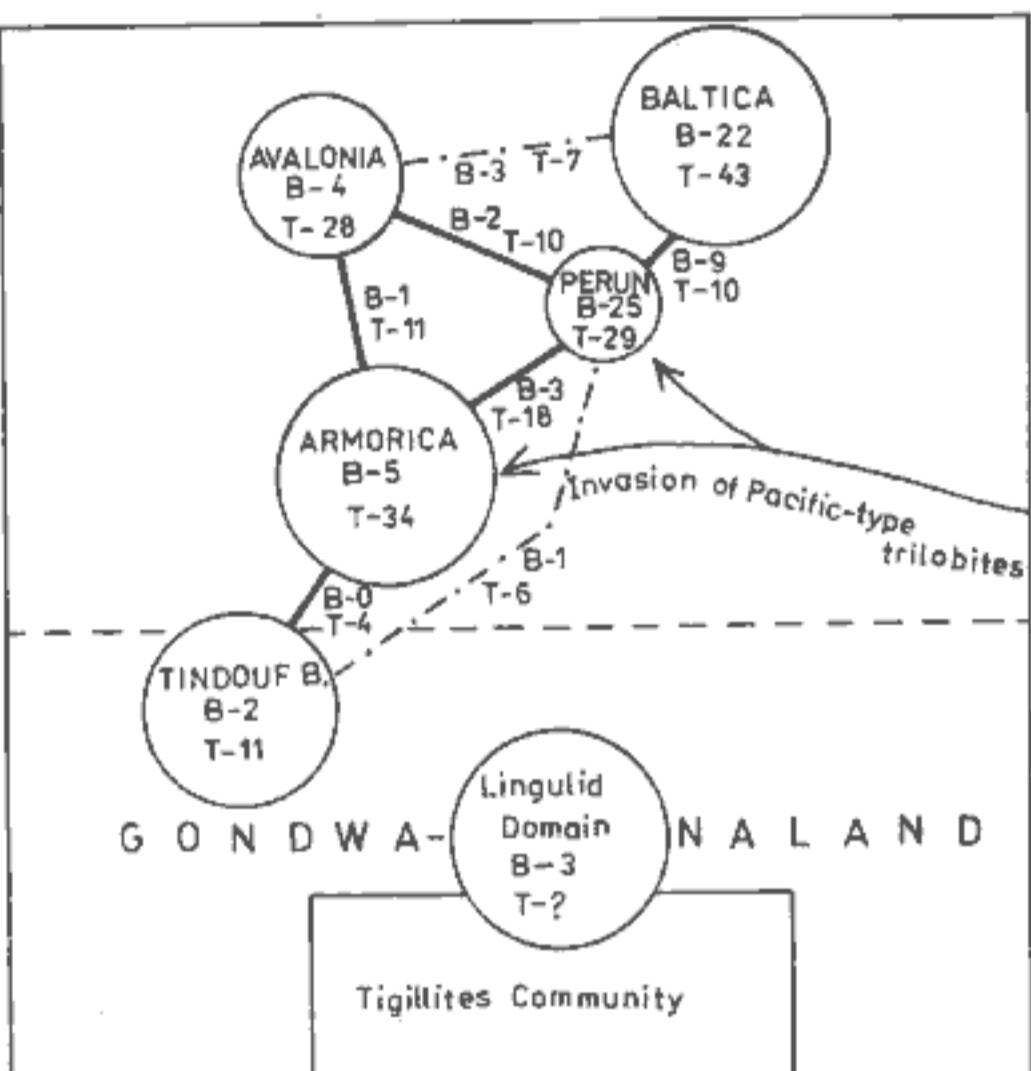
Remarkable feature of the Tremadoc is migration of trilobites between Perunica and East Asian basins as follows from distribution of several "Bohemian" genera in Afghanistan (*Parapilekia*, *Harpides*; Wolfart 1970), China (*Parapilekia*, *Dikelocephalina*, *Niobella*, *Harpides*; Peng 1983; Zhou 1981; Nan 1985; Chang & Fan 1960; Han 1983) and central Asia (*Parapilekia*, *Anacheirurus*, *Dikelocephalina*, *Orometopus*, *Proteuloma*, *Apatokephalus*; Balašova 1961; Apollonov et al. 1984).

Judging from analysis of brachiopods and trilobites, we suppose an invasion of invertebrates into the Prague Basin from the Baltic regions during the lowermost Ordovician transgression. In the Tremadoc, the Tornquist's Sea did not form any serious barrier against migration of invertebrates. An easy interchange of the fauna also existed between Perunica and Armorica at that time as shown by the coefficients of association

Σ genera in common to both assemblages

Σ genera in smaller assemblage

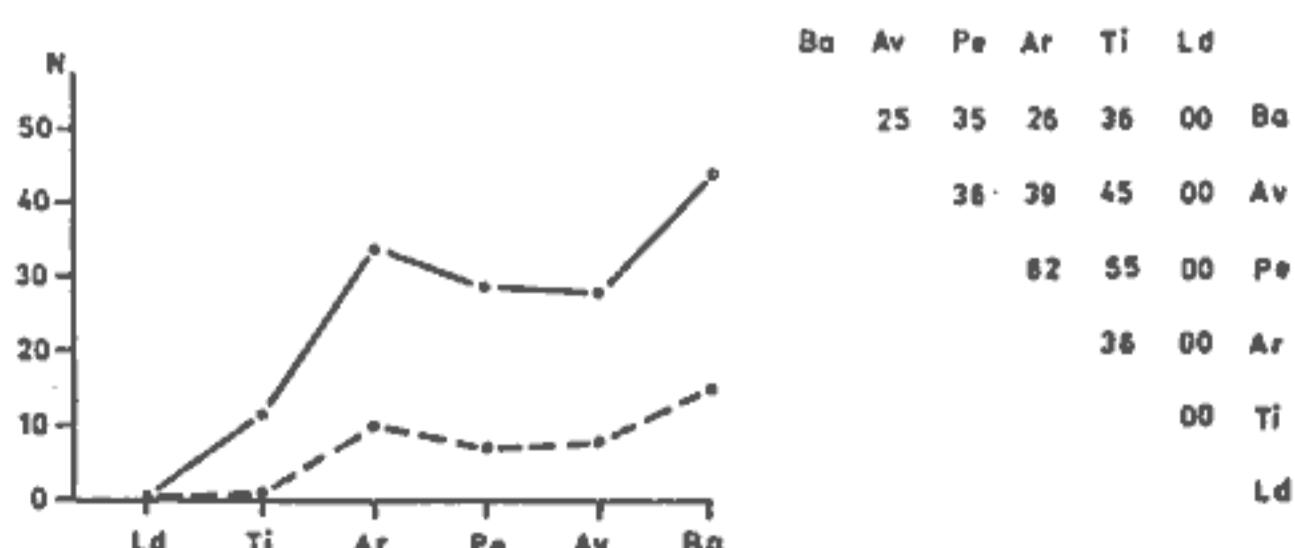
between the brachiopod and trilobite assemblages of separate regions (fig. 6).



6. Relation of separate plates and microplates in the Tremadoc; based on the brachiopod (B) and trilobite (T) assemblages. In the circles: total number of genera; between the circles: number of genera common to both the regions; solid bars: close relation; dot and dashed line: weak relation.

Our conclusions, if correct, must be close to the palaeogeography of the Cambrian. Unfortunately, any information about the Upper Cambrian biota in Perunica

5. Trilobite assemblages in the Tremadoc. Graphs showing decreasing number of genera from the warm-temperature zone toward the circumpolar sphere, and the coefficients of association between 6 regions investigated (explanation: see text-fig. 4).



is missing. For this reason, we have used the Middle Cambrian faunas to compare Perunica, Baltica and Avalonia. As in the Tremadoc, many trilobite genera (about 50 per cent) found in the Přibram-Jince Basin (Bohemia) are in common to Perunica and Baltica, and more than 50 per cent of the Bohemian genera have also been recovered in Armorica (Montagne Noire, Spain). The Mid-Cambrian brachiopods are too low-diversified to warrant a reliable tool for comparison; of Orthida, *Oligomys* indicates a Baltic affinity, whereas *Jamesella* occurs both in the Přibram-Jince Basin and Armorica (Ossa Morena, Spain; Gil Cid & Mélou 1988). *Brahimorthis* has been identified in the Tindouf Basin and Bohemia; *Bohemiella* and *Pompeckium* are probably endemic genera in Bohemia. It is then evident that the gross palaeogeography of the Tremadoc copies the configuration of the Cambrian microcontinents and seas.

Data used for palaeogeographic reconstruction of the Tremadoc Perunica (Prague Basin, Bavaria). Brachiopoda - *Apheoorthina*, *Broeggeria*, *Conotreta*, *Elkanisca*, *Eoorthis*, *Eosiphonotreta*, *Expellobolus*, *Ferrobolus*, *Hyperobolus*, *Jivinella*, *Kolihium*, *Lacunites*, *Leptembolon*, *Lingulella*, *Nanorthis*, *Orbithele*, *Palaeoglossa*, *Poramborthis*, *Protambonites*, *Rosobolus*, *Schmidtites*, *Siphonobolus*, *Thysanobolus*, *Thysanotos*, *Westonisca* (Havliček 1977, 1982; Mergl 1984, 1986).

Trilobita (Bohemia) - *Anacheirurus* (=*Parapilekia nana* in Mergl 1984), *Apatokephalus*, *Bavarilla*, *Ceratopyge*, *Dikelokephalina*, *Eulomina*, *Geragnostus*, *Harpides*, *Hemibarrandia*, *Holoubkovia*, *Holubaspis*, *Neptunagnostella* (=*Geragnostella* after Zhou 1987), *Niobella*, *Orometopus*, *Parabathycheilus*, *Parapilekia*, *Proteuloma* (Mergl 1984); further, the genera *Curiaspis*, *Diceratopyge*, *Hospes*, *Kaufmannia*, *Leimitzia*, *Lichakephalus*, *Lichapyge*, *Macropyge*, *Parabolina*, *Protarchaeogonus*, *Shumardia* and *Triarthrus* were recorded in Bavaria (Leimitz Slates; Sdžuy 1955) but not yet found in Bohemia.

Baltica (Estonia, Pakendorf and Leetse Formations). Brachiopoda - *Eosiphonotreta*, *Foveola*, *Helmersenia*, *Keyserlingia*, *Lacunites*, *Leptembolon*, *Lingulella*, *Orbithele*, *Paldiskia*, *Schizambon*, *Schmidtites*, *Spondylotreta*, *Thysanotos* (Gorjanskij 1969). Further, the chalcedonites of upper Tremadoc age (Holy Cross Mts., Poland) have yielded the following minute brachiopods: *Alichovia*, *Broeggeria*, *Conotreta*, *Ditreta*, *Elliptoglossa*, *Eurytreta*, *Myotreta*, *Paratreta*, *Semitreta* (Biernat 1973; Bednarczyk & Biernat 1978).

Trilobita (Sweden, Norway) - *Agerina*, *Ampyx*, *Apatokephalus*, *Arthrorhachis*, *Bienvillia*, *Boeckaspis*, *Borogothus*, *Ceratopyge*, *Cyclopyge*, *Dikelokephalina*, *Euloma*, *Evropeites*, *Falanaspis*, *Geragnostus*, *Harpides*, *Jujuyaspis*, *Nileus*, *Niobe*, *Niobella*, *Niobina*, *Orometopus*, *Pagometopus*, *Parabolinella*, *Parabolina*, *Parapilekia*, *Peltocare*, *Promegalaspides*, *Saltaspis*, *Shumardia*, *Syphysurina*,

Syphysurus, *Triarthrus*, *Tropidopyge*, *Varvia* (Tjernvik 1956; Henningsmoen 1957, 1959). Further genera in the Baltic regions: *Asaphellus*, *Carolinites*, *Krattaspis*, *Lamanskytes*, *Megalaspides* (*Popovkites*), *Paramegistaspis*, *Proasaphus*, *Ptychometopus*, *Rhinoferus?* (*Popovkiaspis*) (Alichova 1960, Balašova 1976).

Armorica (North-east Spain, Iberian Chains). Brachiopoda - *Ectenoglossa*, *Lingulella*, *Poramborthis*, *Protambonites*, *Tomasina* (Josopait 1972; Havliček & Josopait 1972).

Trilobita (Montagne Noire, Spain) - *Anacheirurus*, *Angelina*, *Apatokephalus*, *Arthrorhachis*, *Asaphellus*, *Ceratopyge*, *Courtessolum*, *Dikelokephalina*, *Euloma*, *Geragnostella*, *Geragnostus*, *Harpides*, *Hemibarrandia*, *Holubaspis*, *Hypermecaspis*, *Leiagnostus*, *Lichakephalus*, *Macropyge*, *Micagnostus*, *Neptunagnostella*, *Niobella*, *Onchonotellus*, *Parabathycheilus*, *Parabolina*, *Parahystricurus*, *Paramegalaspis*, *Pharostomina*, *Phoidagnostoides*, *Phoidagnostus*, *Proteuloma*, *Shumardia*, *Syphysuroides*, *Syphysurus*, *Triarthrus* (Capera et al. 1974, 1975, 1978; Courtessole et al. 1975, 1978, 1981; Pillet et al. 1980; Rábano 1984; Berard 1986).

Gondwana, Tindouf Basin (Morocco, Mauritania). Brachiopoda - *Orbithele*, *Plectorthis* (Havliček 1971; Mergl 1981).

Trilobita - *Asaphellus*, *Asaphopsis*, *Bavarilla*, *Beltella*, *Dikelokephalina*, *Orometopus*, *Parapilekia*, *Pharostomina*, *Platypeltoides*, *Proteuloma*, *Syphysurus* (Destombes 1962, 1967).

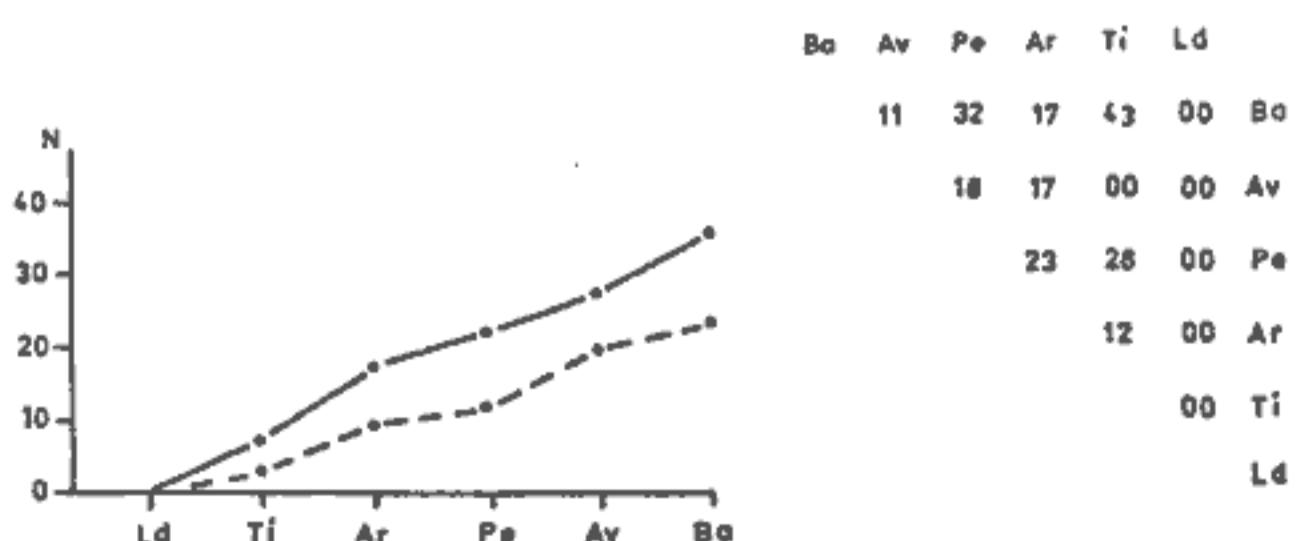
Gondwana, Ghadamis Basin (Tunisia, Libya): Brachiopoda - *Eosiphonotreta*, *Palaeoglossa*, *Tunisiglossa* (Massa, Havliček & Bonnefous 1977). Gondwana, Tigillites Community - "Dinobolus", "Lingulella", *Lingulobolus*, *Westonia* (Legrand, Poueyto & Roux 1959; Legrand 1969; Trompette 1973).

Avalonia (South Wales): Brachiopoda - *Broeggeria*, *Eurytreta*, *Lingulella*, *Palaeobolus* (Cope, Fortey & Owens 1978; Owens, Fortey, Cope, Rushton & Bassett 1982).

Trilobita (England and Wales, Dictyonema flabelliforme to Angelina sedgwicki Zones) - *Acanthopleurella*, *Anacheirurus*, *Angelina*, *Apatokephalus*, *Asaphellus*, *Beltella*, *Bienvillia*, *Boeckaspis*, *Ciceragnostus*, *Dichelepyge*, *Dikelokephalina*, *Geragnostus*, *Leptoplastides*, *Lichapyge*, *Macropyge*, *Micagnostus*, *Myindella*, *Niobella*, *Niobina*, *Orometopus*, *Parabolinella*, *Peltocare*, *Platypeltoides*, *Prospectatrix*, *Proteuloma*, *Pseudokainella*, *Psilocephalina*, *Shumardia* (Thomas et al. 1984).

Arenig

From a global point of view, the Arenig Series represents an eustatic cycle that begins with a transgression and terminates with a regression (Walhall regressive event; Fortey 1984). It is characterized by the first graptoloids without bithecae (Erdmann 1988) and contains a suite of graptolite zones from the earliest *Clonograptus* assemblage to the latest *Didymograptus hirundo* Zone which all can be correlated with the graptolite assemblages of



7. Brachiopod assemblages in the Arenig. Graphs showing decreasing number of genera from the warm-temperature zone toward the circumpolar sphere, and the coefficients of association between 6 regions investigated (explanation: see text-fig. 4).

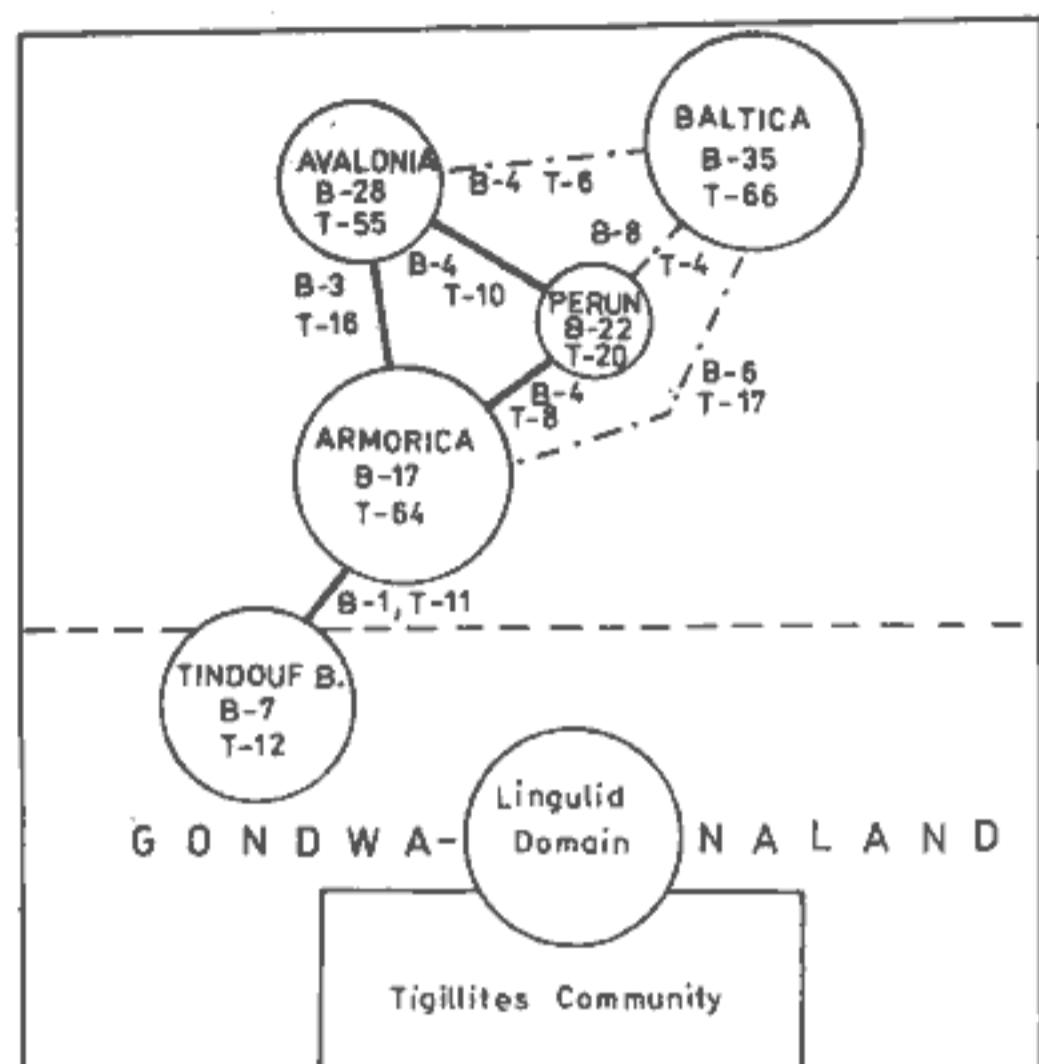
Perunica. Further, the biostratigraphy of the Arenig in the Mediterranean Province is based on the chitinozoans (Paris 1981) and very abundant acritarchs (Cramer & Diéz 1977; Vavrdová 1972).

In Armorica, the Arenig Series is formed as the Armorican Sandstone with abundant trace fossils (*Cruziana*, *Rouaultia*, *Daedalus*, *Rusophycus*) and inarticulate brachiopods (*Ectenoglossa*, *Lingulobolus*, *Lingulepis*) either overlying the Cambrian and Brioherian rocks (e.g. in the Armorican Massif; Babin et al. 1976; and in the Andalusian Basin; Hammann 1976), or resting conformably on the Tremadoc beds (e.g. in Celtiberia; Hammann 1976). A similar development has been found in Thuringia (Perunica) where the Phycodes Group also contains numerous trace fossils.

In Perunica, the Arenig Series is best exposed in Central Bohemia where the Klabava Formation contains in the deepest part of the Prague Basin a complete sequence from the *Clonograptus* assemblage (Hunnebergian) to the top of the *Tetragraptus abbreviatus* Zone; succession of graptolite associations is as follows: 1. The earliest one is dominated by *Clonograptus* sp. in association with less frequent *Desmograptus* sp., *Dendrograptus* sp., and *Acrograptus* sp. (Kraft & Mergl 1979). 2. The shales with *Clonograptus* are overlain with shales of the *Corymbograptus v-similis* Zone containing *Tetragraptus kindlei*, *Expansograptus goldschmidti*, *Acrograptus simulans*, *A. nicholsoni*, *Corymbograptus deflexus*, *C. holubi*, and *C. v-similis* (Kraft 1977). 3. The zone of *Holograptus tardibrachiatus* has yielded except the index species also *Holograptus deani*, *Tetragraptus kindlei*, *Eotetragraptus harti*, *Expansograptus goldschmidti*, *Acrograptus nicholsoni*, *A. infrequens*, *Didymograptus rokykanensis*, and *D. chlupaci* (Kraft 1977). 4. The latest zone has yielded *Holograptus membranaceus*, *Tetragraptus abbreviatus*, *T. cf. bigsbyi*, *T. kindlei*, *Phyllograptus angustifolius*, *Acrograptus nicholsoni*, *A. aff. crassus*, *Azygograptus suecicus*, and *Corymbograptus cejpi* (Kraft 1977).

The chitinozoans have been obtained from all graptolite zones; according to Paris and Mergl (1984), most of them are cosmopolitan species reported from North Africa, south-western Europe, Baltic regions and Canada. In the

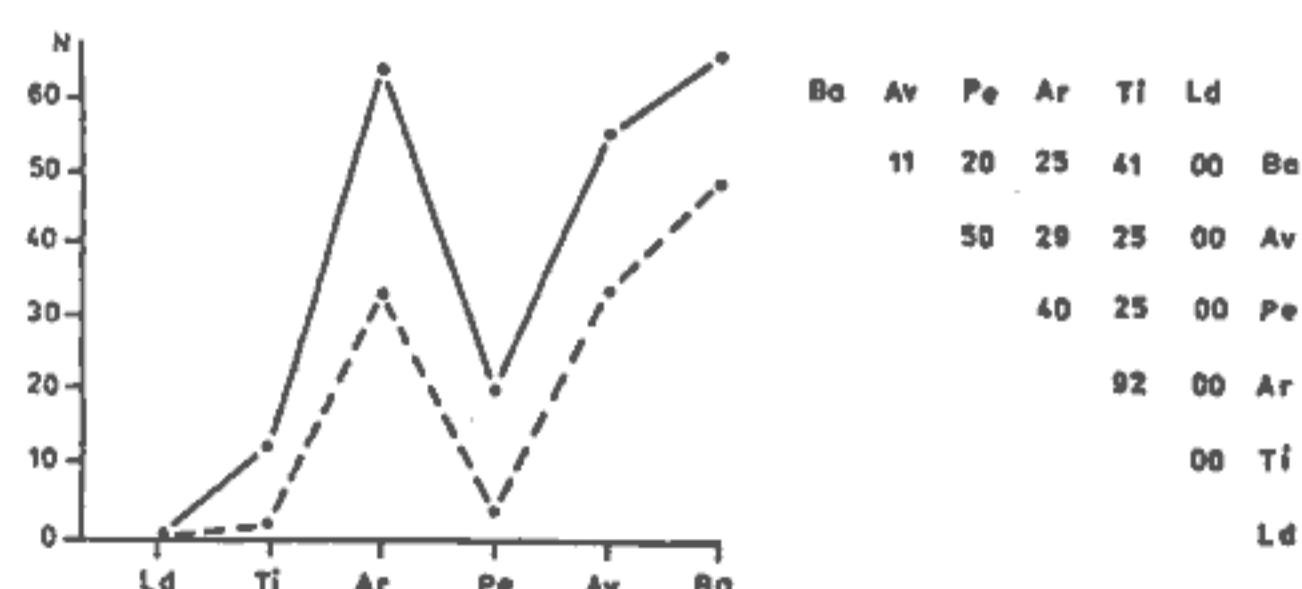
Klabava Formation, the following assemblages have been discerned: *Conochitina symmetrica*, *Tanuchitina achabae*, *Lagenochitina esthonica*, *Laufeldochitina baculiformis* and the latest *Desmochitina bulla*. Recently, rare specimens of the genus *Belonechitina* have also been found in the latest assemblage.



9. Relation of separate plates and microplates in the Arenig; based on the brachiopod (B) and trilobite (T) assemblages (explanation: text-fig. 6).

The acritarchs are abundant through the Arenig Series in the Prague Basin (survey of earlier papers: Vavrdová 1986). Unfortunately, majority of samples analyzed up to now comes from the upper part of the Klabava Formation (i.e. from the *Holograptus tardibrachiatus* and *Tetragraptus abbreviatus* Zones), whereas the lower Klabava Formation is poorly documented. Vavrdová (1986) considered *Arbusculidium filamentosum* and *Baltisphaeridium klabavense* as typical taxa in the Klabava Formation. Recent discoveries in beds corresponding in age to the *Clonograptus* Zone have

8. Trilobite assemblages in the Arenig. Graphs showing decreasing number of genera from the warm-temperature zone toward the circumpolar sphere, and the coefficients of association between 6 regions investigated (explanation: see text-fig. 4).



yielded *Caldariola glabra*, *Stelliferidium cf. trifidum*, *Cymatiogalea messaoudi*, *Rhapaliophora palmata*, and chitinozoans *Conochitina symmetrica* and *?Amphorachitina* (Fatka, in press); this association indicates the latest Tremadoc-lowest Arenig boundary beds. The uppermost part of the Klabava Formation is characterized by *Micrhystridium conobrachium* and *Stelliferidium*.

Shelly fauna and trilobites are poorly diversified and mostly confined to the upper part of the formation.

Transgressive character of the Klabava Formation is apparent from a moderate expansion and deepening of the sea in central Bohemia, sudden change in facies development, and in an influx of new invertebrates into the Prague Basin (Havlíček & Vaněk 1966; Havlíček 1982). The Walhall regression event coincides with an appearance of a sequence of reworked tuffs with carbonate cement, tuffitic and bidetrital limestones in the uppermost Klabava Formation (intertidal to shallow subtidal *Nocturnellia* Community; Havlíček 1982).

The benthic communities of Perunica differ from those of Baltica in lacking numerous orthid and clitambonitid brachiopods as well as the large asaphid trilobites. Common elements to both the regions are *Eosiphonotreta*, *Ephippelasma*, *Nereidella*, *Ranorthis*, and *Rowellella*, and an epiplanktic brachiopod *Paterula*. Also *Celdobolus* may be considered as a North European element in Perunica, because its ancestors should be sought in the Zbilutka and Koziel Beds (Tremadoc of the Holy Cross Mts., Poland: *Obolus complexus* in Bednarczyk 1964). Of trilobites, *Sympysurus* and *Cyrtometopus* indicate a weak Baltic affinity in the upper part of the Klabava Formation.

By contrast to Perunica, the orthids and clitambonitids are rather frequent in Armorica (Montagne Noire); the genera, occurring both in Perunica and Armorica, are *Conotreta*, *Rafanoglossa*, and *Prantlina* of brachiopods, and *Asaphellus*, *Bohemopyge*, *Colpocoryphe*, *Euloma* (*Calymenopsis*), *Geragnostus*, *Microparia*, and *Sympysurus* of trilobites. The faunal relation of Perunica to Gondwana (Tindouf Basin) is even weaker, because *Ranorthis* is the only articulate brachiopod recorded in both the regions. By contrast to the Tremadoc, the Avalonian affinity is clearly apparent in the Perunican Arenig. The following genera occur in both the regions: *Nocturnellia*, *Palaeoglossa*, *Paterula*, *Rafanoglossa*, *Asaphellus*, *Bohemopyge*, *Colpocoryphe*, *Ectillaenus*, *Illaenopsis*, *Microparia*, *Ormathops*, *Placoparia*, and *Pricyclopype*.

In general, distribution of the brachiopod and trilobite genera clearly indicates a weaker Baltic affinity of Perunica than in the Tremadoc, but a much closer relation to West Avalonia (several trilobites conspecific!). For this reason, we may suppose that the Tornquist's Sea formed a more serious barrier against migration of invertebrates than in the Tremadoc. On the other hand, the interchange of the shelly fauna and trilobites was fairly easy between

Perunica, Avalonia, and Armorica at least in the upper Arenig, and thus it supports the idea of Cocks and Fortey (1990) that Avalonia was welded to Gondwana (including West Europe and Bohemia) during the lower Ordovician till the upper Llanvirn. The faunal differences between the Gondwanan epicratonic basins and the basins of Perunica are greatly influenced not only by the palaeogeography of that time but also by climatic-latitudinal control.

Data used for the palaeogeographic reconstruction of the Arenig Perunica (Prague Basin, based on upper part of the Klabava Formation). Brachiopoda - *Acanthambonia*, *Celdobolus*, *Conotreta*, *Elkanisca*, *Eosiphonotreta*, *Ephippelasma*, *Ferrax*, *Koligium*, *Leptembolan*, *Lingulella*, *Nereidella*, *Nocturnellia*, *Orbithele*, *Palaeoglossa*, *Paldiskites*, *Paterula*, *Prantlina*, *Rafanoglossa*, *Ranorthis*, *Rowellella*, *Schmidtites*, *Styxorthis* (Havlíček 1977, 1982a; Mergl 1986).

Trilobita - *Asaphellus*, *Aspidaeglina*, *Bohemolichas*, *Bohemopyge*, *Colpocoryphe*, *Cyrtometopus* (recently discovered by M. Doubrava), *Ectillaenus*, *Euloma* (*Calymenopsis*), *Geragnostus*, *Illaenopsis* (=*Rokycania* in Přibyl & Vaněk 1965), *Klabavia*, *Leiagnostus*, *Microparia*, *Neptunagnostella*, *Ormathops*, *Placoparia* (*Placoparia*), *Pliomerops*, *Pricyclopype*, *Pseudopetigurus*, *Sympysurus* (Havlíček & Vaněk 1966).

Baltica (Baltic regions, Volchov Formation). Brachiopoda - *Angusticardinia*, *Antigonambonites*, *Apomatella*, *Conotreta*, *Eoconulus*, *Eosiphonotreta*, *Ephippelasma*, *Eurytreta*, *Glossorthis*, *Ingria*, *Lingulops*, *Lycophoria*, *Myotreta*, *Nothorthis*, *Orthambonites*, *Orthis*, *Panderina*, *Paurorthis*, *Paterula*, *Platystrophia*, *Plectella*, *Porambonites*, *Prantlina?*, *Productorthis*, *Pseudocrania*, *Quasithambonia*, *Ranorthis*, *Rauna*, *Rowellella*, *Scaphelasma*, *Spondylotreta*, *Torynelasma*, *Westonia* (Alichova 1953; Rubel 1961; Gorjanskij 1969; Biernat 1973; Bednarczyk & Biernat 1978). Further, *Iru* and *Progonambonites* have been recorded only in the Holy Cross Mts., Poland (Bednarczyk 1964).

Trilobita (Sweden, Norway: Hunneberg Group, *Plesiomegalaspis armata* to *P. planilimbata* Zones; Billingen Group, *Megalaspides dalecarlicus* to *Megistaspis limbata* Zones) - *Agerina*, *Ampyx*, *Ancyginaaspis*, *Apatocephalus*, *Arthrorhachis*, *Asaphus*, *Bornholmaspis*, *Cybele*, *Cyclopype*, *Diaphanometopus*, *Dysplanus*, *Ekeraspis*, *Eurobergia*, *Euloma*, *Falanaspis*, *Geragnostus*, *Glaphurina*, *Harpides*, *Homalopyge*, *Hunnebergia*, *Illaneus*, *Laneites*, *Lannacus*, *Lapidaria*, *Leiagnostus*, *Lonchodus*, *Megalaspides*, *Megistaspidella* (*Megistaspidella*), *M. (Spinopyge)*, *Megistaspis* (*Megistaspis*), *M. (Megistaspinus)*, *Menoparia*, *Metaptychopyge*, *Mischynogorites*, *Nileus*, *Niobe*, *Niobella*, *Orometopus*, *Parabolinella*, *Paramegistaspis*, *Paraptychopyge*, *Plesiomegalaspides*, *Pogrebovites*, *Promegalaspides*, *Pseudoptychopyge*, *Ptychopyge*, *Raymondaspis*, *Remopleuridiella*, *Rhinoserus* (*Rhinoserus*), *R. (Ropsohiaspis)*, *Saltaspis*, *Scotoharpes*, *Shumardia*, *Sympysurus*, *Telephina*, *Triarthrus*, *Trinucleoides*, *Varvia* (Tjernvik 1956; Poulsen 1965; Balašova 1976). Further, the genera *Onchometopus*, *Metopolichas*, *Pliomera*, *Protoptychopyge*, *Pseudoasaphinus*, *Pseudoasaphus*, *Pterygometopus*, *Rhinoserus* (*Lawiaspis*) occur in the Volchov Formation (Baltic regions: Alichova 1960; Balašova 1976).

Armorica (Montagne Noire). Brachiopoda - *Aportophylla*, *Ocorthis*, *Orthambonites*, *Conotreta*, *Ectenoglossa*, *Gonambonites*, *Hesperonomia*, *Lingulepis*, *Lingulobolus*, *Paurorthis*, *Pleurorthis*, *Prantlina*, *Progonambonites*, *Rafanoglossa*, *Ranorthis*, *Sinorthis*, *Spondylossela* (Havlíček 1980; Mélou in Babin et al. 1982).

Trilobita (Montagne Noire, Spain) - *Ampyx*, *Ampyxinella* (*Eoampyxinella*), *Anacheirus*, *Apatocephalus*, *Arthrorhachis*, *Asaphellina*, *Asaphellus*, *Asaphopoides*, *Basiliella*, *Birmanites*, *Bohemopyge*, *Carolinites*, *Colpocoryphe*, *Cyclopype*, *Degamella*, *Dictyocephalites*, *Ekeraspis*, *Euloma*, *Foulonia*, *Geragnostella*, *Geragnostus*, *Hanchungolithus*, *Harpidella*, *Harpides*, *Hoekaspis*,

Homagnostoides, *Hungioides*, *Hunnebergia*, *Hystricurus*, *Illaenopsis*, *Kodymaspis*, *Leignostus*, *Megalaspidella*, *Micragnostus* (=*Anglagnostus*), *Microparia*, *Nanillaenius*, *Neseuretus*, *Niobe*, *Niobella*, *Ogygiocaris*, *Ogyginus*, *Orometopus*, *Paramegalaspis*, *Parabathycheilus*, *Pharostomina*, *Platycalymene*, *Platycoryphe*, *Platypeltoides*, *Plesiomegalaspis*, *Pliomerops*, *Pradesia*, *Pradoella*, *Prionocheilus*, *Prospectatrix*, *Pterygometopus*, *Raymondaspis*, *Salterocoryphe*, *Selenopeltis* (*Languedopeltis*), *S. (Selenopeltis)*, *Shumardia*, *Sympysurus*, *Taihungshania*, *Thoralocolus*, *Thoralocoryphe* (Capéra et al. 1974, 1975, 1978; Courteille et al. 1975, 1978, 1981; Pillet & Courteille 1980; Rábano 1984; Berard 1986; Pillet 1988).

Gondwana (Tindouf Basin, Morocco). Brachiopoda - *Angusticardinia*, *Incorthis*, *Orbithele*, *Paurorthis*, *Plectorthis*, *Ranorthis*, *Tarfaya* (Havlíček 1971; Mergl 1981, 1988).

Trilobita - *Ampyx*, *Apatokephalus*, *Anacheirurus*, *Bavarilla*, *Colpocoryphe*, *Euloma*, *Neseuretus*, *Parabathycheilus*, *Plesiomegalaspis*, *Pterygometopus*, *Prionocheilus*, *Sympysurus* (Destombes 1962, 1967).

Avalonia (Shelve district, Shropshire; Myton Flags). Brachiopoda - *Apsotreta*, *Astraborthis*, *Dalmanella*, *Diparelasma*, *Euorthisina*, *Hesperonomia*, *Monobolina*, *Nocturnellia*, *Orthis*, *Palaeoglossa*, *Paralenorthis* (=*Lenorthis* in Williams 1974), *Paterula*, *Protoskenidioides*, *Rafanoglossa* (=*Pseudolingula* in Williams 1974), *Schizotreta* (Williams 1974). The peninsular Celtic Province (Treiorwerth Formation, Anglesey) has yielded the following brachiopods: *Fsynonia*, *Hesperonomiella*, *Monorthis*, *Orthambonites*, *Paralenorthis* (=*Lenorthis alata* in Bates 1969), *Productorthis*, *Rectotrophia*, *Reinversella*, *Rhynchorthis*, *Rugostrophia*, *Skenidioides*, *Treioria*, *Tritoechia* (Bates 1968, Neuman & Bates 1978).

Trilobita (England, Wales) - *Agerina*, *Ampyx*, *Anebolithus*, *Arthrorachachis*, *Asaphellus*, *Barrandia*, *Bergamia*, *Bienvillia*, *Bohemilla* (*Fenniops*), *Bohemopyge*, *Circulocrania*, *Cnemidopyge*, *Colpocoryphe*, *Corrugatagnostus*, *Cyclopyge*, *Degamella*, *Dindymene*, *Dionide*, *Dionidella*, *Ectillaenus*, *Ellipsotaphrus*, *Furcalithus*, *Gastropolis*, *Girvanopyge*, *Gog*, *Gymnostomix*, *Heterocyclopyge*, *Hypermecaspis*, *Illaenopsis*, *Leiagnostus*, *Leioshumardia*, *Macrogrammus*, *Megalaspidella*, *Merlinia*, *Microparia* (*Microparia*), *M. (Quadrappyge)*, *Monella*, *Mytonia*, *Neseuretus*, *Novakella*, *Ogyginus*, *Ormathops*, *Placoparia*, *Placoparia*, *Porterfieldia*, *Pricyclopyge* (*Bicyclopyge*), *P. (Pricyclopyge)*, *Prospectatrix*, *Psilacella*, *Sagavia*, *Segmentagnostus*, *Seleneceme*, *Selenopeltis*, *Shumardia* (*Conophrys*), *S. (Shumardia)* (Thomas et al. 1984; Fortey & Owens 1987).

Llanvirn

The weak uppermost Arenig regression event was succeeded by a further marine transgression which reached its peak in the Mediterranean Province during the Llanvirn with a deposition of shales accompanied by iron-bearing sediments (Babin et al. 1976). The Arenig sandstones (e.g. the Grès Armorican Formation in Armorica, the Phycodes Group in Perunica, the Zini Sandstone in the Tindouf Basin, North Africa) are usually overlain by a rather uniform sequence of dark to black shales indicating a changeover toward an anoxic regime, occasionally with sandstone and ferrolite intercalations and fossiliferous nodules (e.g. Urville Formation, lower parts of the Postolonnec and Traveusot Formations, Armorican Massif; further lower parts of the Luarca, Cacemes, and Rio Shales Formations, Iberian Peninsula; further Tachilla Formation, Tindouf Basin, Morocco, and

radioactive shales of the Bir-Ben-Tartar Fm., Ghadamis Basin, Tripolitania; further Šárka and Griffelschiefer Formations, Perunica). The Llanvirn usually bears a typical suite of graptolite assemblages which enabled an easy correlation among the separate regions. Moreover, the biostratigraphy of the Mediterranean Llanvirn is based on the chitinozoans (Paris 1981), acritarchs (Elaouad - Debbaj 1984; Vavrdová 1977), and trilobites. A famous trilobite is *Neseuretus* which is a significant inhabitant of the high-latitude environment (Fortey & Morris 1982; Cocks & Fortey 1982). It is spread from the Saudi Arabia in the East to the Tindouf Basin in the West; it was also recorded in South China. Further, *Neseuretus* is frequent in Armorica but never found in Perunica, because the latter region occurred at that time beyond the circumpolar sphere in a temperature zone.

In Perunica, the Llanvirn was verified on palaeontological grounds in the Prague Basin (Šárka Formation) and in the Saxothuringian Zone (Griffelschiefer). As in Armorica, the earliest Llanvirn is distinguished by a further marine transgression, sudden change in facies development (appearance of black shales and sedimentary iron ores), and sudden influx of new benthic and planktic biotas. Moreover, the tectonic deformations at the Arenig/Llanvirn boundary caused in Bohemia not only a rapid deepening of the Prague Basin but also a fracturing of marginal parts of the basin where the minor and variously uplifted blocks were exposed to a post-Arenig but pre-Llanvirn erosion (territory of Prague: Havlíček 1982).

In the central part of the Prague Basin, the Llanvirn Series is formed as a black-shale sequence without breaks in sedimentation, in many areas bearing numerous graptolites. The earlier *Corymbograptus retroflexus* Zone comprises *Corymbograptus retroflexus*, *C. imminutus*, *Expansograptus stanislavi*, *Climacograptus novaki*, *Pseudoclimacograptus klabavensis*, *Didymograptus artus*, *D. incertus*, *D. halli* a.o. less frequent graptolites. Further, the lower part of the zone contains locally (e.g. at Krušná hora, north-western limb of the basin) *Expansograptus ferrugineus*, *E. hudlicensis*, *Paraulograptus expectans*, *Nicholsonograptus leptotheca*, *Pseudoclimacograptus paradoxus*, *Acrograptus lipoldi*, and *Aulograptus feistmanteli* (Bouček 1973). It is probable that the base of the Šárka Formation corresponds to the base of the Anglo-Welsh *Didymograptus artus* Biozone. Upper part of the Šárka Formation is distinguished by numerous *Didymograptus clavulus* and *D. pseudogeminus*.

A significant feature of the lowest Šárka Formation is a sudden appearance of chitinozoans *Cyathochitina campanulaeformis*, *Desmochitina minor*, and *Sagenachitina oblonga* (Paris & Mergl 1984) which all are index species of the zone 6 of Paris (1981), whereas the lower Llanvirn zone 5 (i.e. *Cyathochitina calix*) has not yet been proved in Bohemia. Also the oolitic haematite

(Ejpovice) has yielded the chitinozoans *Sagenachitina*, *Belonechitina* and *Cyathochitina*. According to Vavrdová (1986), the characteristic species of richly diversified acritarchs are *Diacodium normale*, *Stellechinatum celestum*, *Petaloferidium florigerum* and *Sylvanidium operculatum* (all dark shales of the Šárka Formation). Some acritarch taxa (e.g. *Frankea*) typical of the Llanvirn Series appear in Bohemia as early as in the uppermost Klabava Fm.

The infaunal and epibenthic brachiopods are extremely rare in the Prague Basin, whereas the vagile and nekto-benthic elements are prolific (bivalves, gastropods, hyolithids, echinoderms, trilobites). An interesting element is *Boiophytion pragense* considered either as an early land-plant, or as a near-shore plant partly emergent above the sea-level (Obrhel 1964). (List of species and survey of communities in the Šárka Formation: see Havlíček & Vaněk 1966, 1990.)

The fossil record in the Saxothuringian Zone is much weaker than in the Prague Basin. The Griffelschiefer has yielded *Dionide*, *Ectillaenus*, *Hungioides*, *Microparia*, *Nerudaspis*, *Novakella*, *Pricyclopse*, and *Selenopeltis* (Freyberg 1923; Richter & Richter 1927, 1954; Siegfried 1969).

The Perunican benthic fauna differs from that of Baltica in greatly reduced sessile benthos, namely in absence of numerous orthids, clitambonitids, and porambonitids. In the Prague Basin, the trilobites are highly diversified and contain both the nekto-benthic and planktic elements; of trilobites, only the pandemic *Illaenus* and *Prionocheilus* are in common to Perunica and Baltica, whereas the others are typical inhabitants of the Mediterranean (=*Selenopeltis*) Province.

A close relation of Perunican and Armorican faunas is apparent from the fact that many genera are common to both the regions: *Asaphellus*, *Bathycheilus*, *Colpocoryphe*, *Ectillaenus*, *Hungioides*, *Illaenus*, *Nerudaspis*, *Nobiliasaphus*, *Pateraspis*, *Placoparia* (*Placoparia*), *Pricyclopse* (*Bicyclopyge*), *Prionocheilus* and *Selenopeltis*. Likewise close is the faunal relation between the Prague Basin and East Avalonia in the lower Llanvirn.

An interesting matter of Perunica is the early Llanvirn invasion of those trilobites which occurred in the

Avalonian and Armorican basins as early as in the Arenig, e.g. *Cyclopyge*, *Degamella*, *Dionide*, *Ellipsotaphrus*, *Kodymaspis*, *Novakella*, *Pricyclopse* (*Bicyclopyge*), *Prionocheilus*, and *Selenopeltis*.

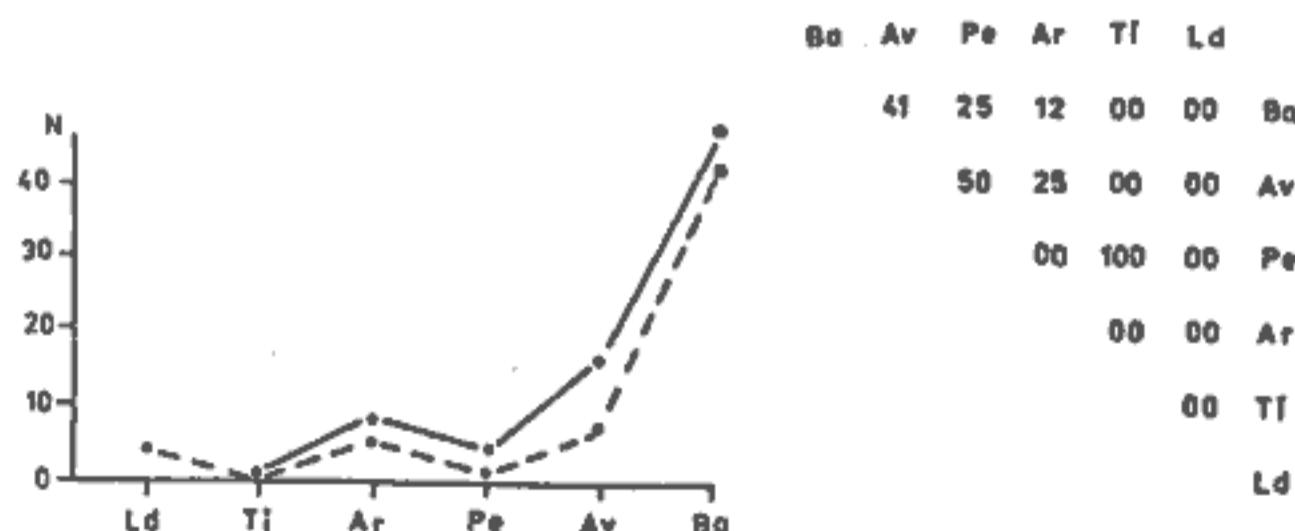
As follows from analysis of invertebrates, the Tornquist's Sea (including surface currents) was a significant barrier prohibiting an interchange of the shelly fauna and trilobites during the Llanvirn. On the other hand, easy migration routes existed between Perunica, Armorica, and Avalonia at that time; moderately impoverished fauna in North Africa (Ghadamis and Tindouf Basins) may be better explained on climatic-latitudinal terms than by the existence of extensive oceans between Gondwana, Avalonia and Perunica. This statement accords with a new palaeogeographic reconstruction suggested by Cocks and Fortey (1990) showing that Avalonia separated from Gondwana (including central and western Europe) after the Llanvirn.

Data used for palaeogeographic reconstruction of the Llanvirn Perunica (Prague Basin, Šárka Formation). Brachiopoda - *Eodalmanella*, *Euorthisina*, *Palaeoglossa*, *Paterula* (Havlíček 1977, 1982).

Trilobita - *Areiaspis*, *Asaphellus*, *Bathycheilus*, *Bohemilla*, *Bohemolichas*, *Bohemopyge*, *Colpocoryphe*, *Corrugatagnostus*, *Cyclopyge*, *Degamella*, *Dionide*, *Ectillaenus*, *Ellipsotaphrus*, *Eoharpes*, *Gamops*, *Geragnostella*, *Granuloagnostus*, *Hungioides*, *Illaenus*, *Kodymaspis*, *Leiagnostus*, *Microparia*, *Neptunagnostella*, *Nerudaspis*, *Nobiliasaphus*, *Novakella*, *Oculagnostus*, *Ormathops*, *Osekaspis*, *Parabarrandia*, *Pateraspis*, *Placoparia* (*Placoparia*), *Plasiaspis*, *Pliomerops*, *Pricyclopse* (*Bicyclopyge*), *P.* (*Pricyclopse*), *Prionocheilus*, *Protostygina*, *Raphiophorus*, *Rokycanocoryphe*, *Selenopeltis*, *Sphaeragnostus*, *Symphysurus*, *Symphysops*, *Trinucleoides*, *Uralichas* (Pek & Vaněk 1989).

Baltica (Baltic regions, Kunda and Aseri Formations). Brachiopoda - *Athiella*, *Antigonambonites*, *Christiania*, *Clitambonites*, *Conotreta*, *Cyrtonotella*, *Eoconulus*, *Eosiphonotreta*, *Estlandia*, *Glossorthis*, *Gonambonites*, *Hemipronites*, *Ingria*, *Inversella*, *Iru*, *Lacunarites*, *Leptotillum*, *Lycophoria*, *Myotreta*, *Nicolella*, *Orthambonites*, *Orthis*, *Oslogonites*, *Pahlenella*, *Paterula*, *Paurothis*, *Platystrophia*, *Plectambonites*, *Porambonites*, *Productorthis*, *Progonambonites*, *Pseudocrania*, *Rhynchocamara*, *Scaphelasma*, *Septomena*, *Sowerbyella*, *Torynelasma*, *Uko*, *Vellamo* (Röömusoks 1963, 1989; Rubel 1961, 1963; Gorjanskij 1969). Further genera: *Acanthambonia*, *Biernatia*, *Dictyonites*, *Numericoma*, *Physotreta*, *Pseudolingula*, *Rowellella*, *Spinilingula*, *Spodylotreta* (Sweden; Holmer 1989).

Trilobita (Sweden, Norway, Baltic regions) - *Apianurus*, *Asaphus* (*Asaphus*), *A.* (*Multiiasaphus*), *A.* (*Neoasaphus*), *Bergamia*, *Boedaspis*,



10. Brachiopod assemblages in the Llanvirn. Graphs showing decreasing number of genera from the warm-temperature zone toward the circum-polar sphere, and the coefficients of association between 6 regions investigated (explanation: see text-fig. 4).

Botrioides, *Calyptaulax*, *Celmus*, *Chasmops*, *Cyclopyge*, *Cyrtometopus*, *Dubovikites*, *Dysplanus*, *Geragnostus*, *Goniotelina*, *Gravicalymene*, *Hallanta*, *Illaenus*, *Lichas*, *Megistaspidella* (*Spinopyge*), *Metopolichas*, *Miraspis*, *Niobe*, *Oculoagnostus*, *Ogygiocaris*, *Panderia*, *Periallaspis*, *Platillaenus*, *Pseudoasaphus*, *Raymondaspis*, *Remopleuridiella*, *Rhinoferus* (*Lawiaspis*), *Robergia*, *Sculptaspis*, *Sphaerocoryphe*, *Stapeleyella*, *Telephina* (*Telephina*), *T.* (*Telephops*), *Valdaites*, *Volchovites* (Poulsen 1965; Balašova 1976).

Armorica (Armorican Massif, central Portugal, central-Iberian zone). Brachiopoda - *Apollonorthis*, *Cacemia*, *Macrocoelia*, *Monobolina*, *Monorthis*, *Orthambonites*, *Schizocrania*, *Tissintia* (Mitchell 1974; Mélou 1976; Gutierrez-Marcos et al. 1984).

Trilobita - *Asaphellus*, *Bathycheilus*, *Colpocoryphe*, *Crozonaspis*, *Ectillaenus*, *Eccoptochile*, *Eodalmanitina*, *Geragnostella*, *Geragnostus*, *Hungiooides*, *Kerfornella*, *Kloucekia*, *Leiagnostus*, *Morgatia*, *Neseuretus*, *Nobiliasaphus*, *Ogyginus*, *Ogygiocaris*, *Ogygites*, *Parabathycheilus*, *Pateraspis*, *Placoparia* (*Placoparia*), *Plaesiacomia*, *Platycoryphe*, *Pradoella*, *Pricyclopyphe*, *Prionocheilus*, *Pterygometopus*, *Retamaspis*, *Salterocoryphe*, *Selenopeltis*, *Toletanaspis*, *Uralichas*, *Zeliszkella* (Henry 1980; Rábano 1984; Gutierrez-Marcos et al. 1984).

Gondwana (Tindouf Basin). Brachiopoda - *Euorthisina*.

Trilobita - *Bathycheilus*, *Colpocoryphe*, *Ectillaenus*, *Eohomalontus*, *Neseuretus*, *Ogygiocaris*, *Ormathops*, *Placoparia* (*Placoparia*), *Plaesiacomia*, *Selenopeltis*, *Zeliszkella* and not determined *Trinucleidae* and *Lichidae* (Destombes 1967, 1972).

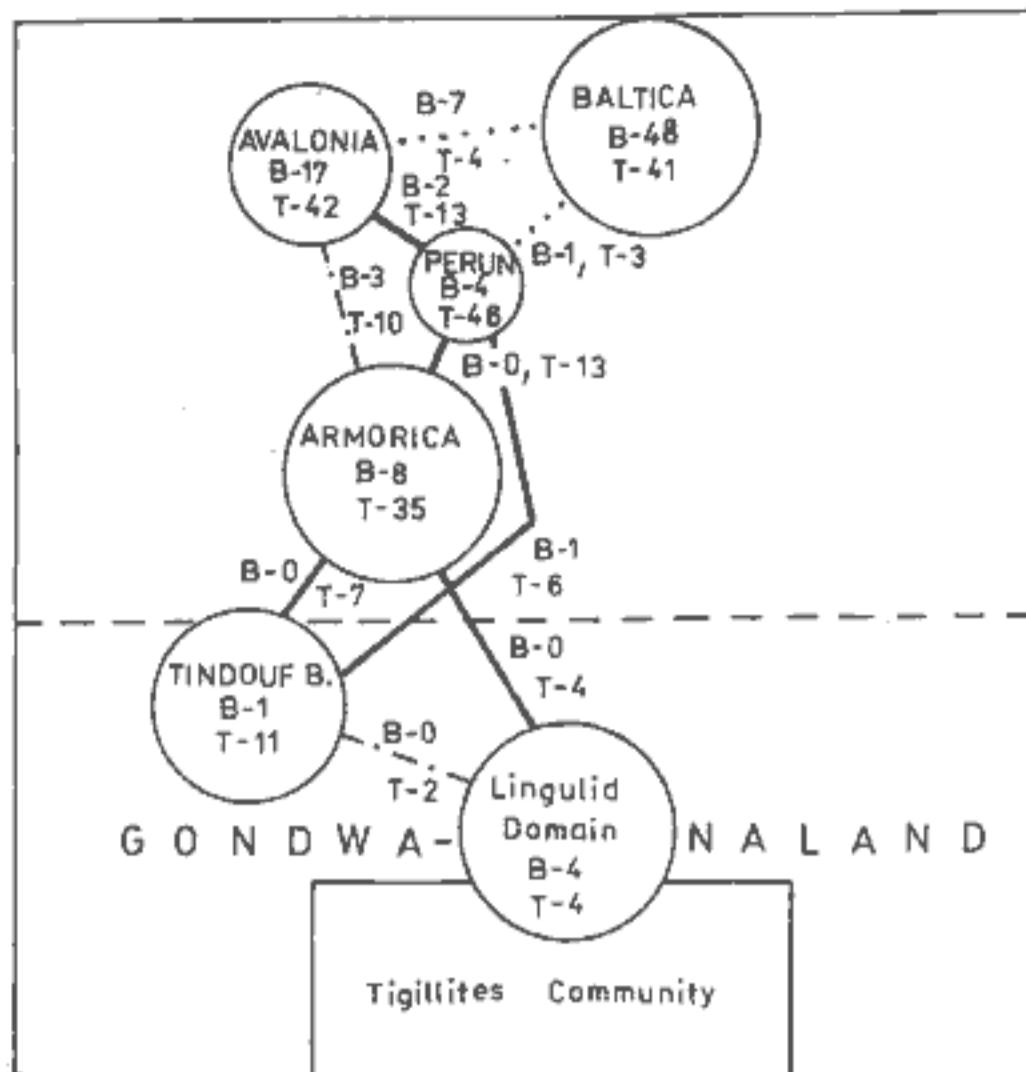
Gondwana (Ghadamis Basin, Bir-Ben-Tartar Formation, *Didymograptus murchisoni* Zone). Brachiopoda - *Lingulella*, *Orbiculothyris*, *Schmidtites*, *Trematis* (Massa, Havlíček & Bonnefous 1977).

Trilobita - *Crozonaspis*, *Neseuretus*, *Ogyginus*, *Placoparia* (Cocks & Fortey 1988).

Avalonia (Shelf Inlier). Brachiopoda - *Conotreta*, *Dalmanella*, *Eocratia*, *Orthis*, *Palaeoglossa*, *Paldiskites* (= *Obolus subditivus* in Williams 1974), *Paterula*, *Rafanoglossa* (*Pseudolingula* in Williams 1974), *Rafinesquina*, *Schizocrania*, *Schizotreta*, *Tissintia* (Williams 1974); further *Ahtiella*, *Antigonambonites*, *Ateleasma*, *Orthambonites*, *Productorthis* (Anglesey, Bod Deiniol Formation; Neuman & Bates 1978).

Trilobita (England, Wales) - *Ampyx*, *Anabolithus*, *Barrandia*, *Basilicus*, *Bergamia*, *Bettonia*, *Bohemilla*, *Cornovica*, *Corrugatagnostus*, *Dionide*, *Ectillaenus*, *Ellipsotaphrus*, *Flexicalymene*, *Gastropolus*, *Girvanopyge*, *Illaenopsis*, *Leiagnostus*, *Marrolithus*, *Merlinia*, *Metopolichas*, *Microparia*, *Ogyginus*, *Ogygiocarella*, *Ogygiocaris*, *Ormathops*, *Placoparia* (*Placoparia*), *Placoparina*, *Plaesiacomia*, *Platycalympene*, *Platycoryphe*, *Porterfieldia*, *Pricyclopyphe* (*Bicyclopyge*), *P.(Pricyclopyphe)*, *Prionocheilus*, *Protolloydolithus*, *Segmentagnostus*, *Seleneceme*, *Selenopeltis*, *Sphaeragnostus*, *Stapeleyella*, *Trinucleus*, *Whittardolithus* (Hughes 1969; Hughes et al. 1975; Rushton & Hughes 1981; Thomas et al. 1984).

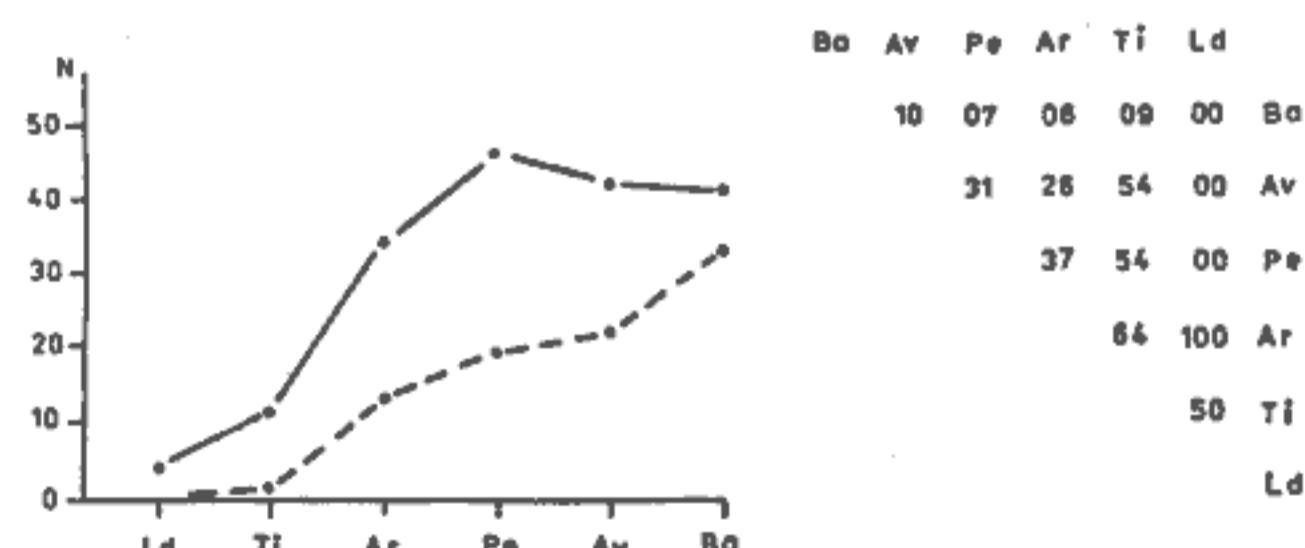
11. Trilobite assemblages in the Llanvirn. Graphs showing decreasing number of genera from the warm-temperature zone toward the circumpolar sphere, and the coefficients of association between 6 regions investigated (explanation: see text-fig. 4).



12. Relation of separate plates and microplates in the Llanvirn; based on the brachiopod (B) and trilobite (T) assemblages (explanation: see text-fig. 6).

Dobrotivá

The Dobrotivá Series was suggested by Havlíček and Marek (1973) for a sequence overlying the "Didymograptus" shales of the Llanvirn Series and underlying a thick sequence of shales and sandstones bearing the richly diversified *Aegirocera-Drabovia* fauna (i.e. the Beroun Series). The base of the Dobrotivá can be compared to the lowermost Llandeilo of the British scale as both contain the index graptolite "*Glyptograptus teretiusculus*"; on the other hand, the upper limits of the Dobrotivá and Llandeilo cannot be precisely correlated because of different faunal content. The upper part of the Dobrotivá Series is distinguished by the *Cryptograptus tricornis* Zone (Havlíček & Vaněk 1966; Bouček 1973), that of the Llandeilo is assigned to the lower part of the *Nemagraptus gracilis* Zone, whereas the upper part of this zone extends to the lower Caradoc (Williams et al. 1972). Even in the case we succeed in finding *Nemagraptus*



gracilis in Bohemia, we will not be sure if the layer having yielded this graptolite was of the upper Llandeilo or lower Caradoc age. For this reason, the best way to stabilize the Ordovician stratigraphy in the Mediterranean Province was to propose the Dobrotivá as a new series ranging from the base of the "*Glyptograptus teretiusculus*" Zone to the top of the *Cryptograptus tricornis* Zone.

In contrast to the preceding Ordovician series, the Dobrotivá does not begin with a marked transgression. In the Mediterranean Province, the black-shale sedimentation continued from the Llanvirn to the Dobrotivá, with more frequent sandstone beds in the latter series. A common presence of sandstones may be explained either by tectonic deformations of the basins and adjacent areas, or by the gradual shallowing of the basins (e.g. the Andalusian Basin, area between Almadén and Alcaraz; Hammann 1976; Tindouf Basin, Premier Bani Formation; Destombes 1967, 1971). As the Llanvirn/Dobrotivá boundary was not associated with any abrupt change in facies development, the two series are mainly distinguishable on palaeontological grounds (e.g. on the study of graptolites and microphytoplankton). In Armorica, the boundary falls within thick sequences of the Cacemes Formation (Portugal), "Tristani Shales" (Central-Iberian Zone), Luarca Shales Formation (Cantabrian and Westasturian-Leonesian Zones), and Postolonnec Formation (Armorican Massif); the lower parts of these units should be assigned to the Llanvirn owing to the presence of numerous didymograptids, the upper parts bearing "*Glyptograptus teretiusculus*" and *Placoparia (Coplacoaria) borni* are of the Dobrotivá age.

In the Mediterranean Province, the lower Dobrotivá is distinguished by the presence of "*Glyptograptus teretiusculus*" which is often accompanied by *Gymnograptus linnarssoni* in the Armorican Massif, Spain and Portugal; the latter graptolite, however, has not yet been found in Perunica. In the Prague Basin (Perunica), the upper Dobrotivá is marked by numerous rhabdosomes of *Cryptograptus tricornis* but rare specimens of the index trilobite *Placoparia (Coplacoaria) borni* (junior synonym: *P. (C.) antiopa*; in Moravec 1990). On the other hand, the graptolites are

absent in the upper Dobrotivá of the Iberian peninsula. Instead of them, *Placoparia (Coplacoaria) borni* has been used as an index trilobite for the upper Dobrotivá. Moreover, it may serve as a reliable marker for a correlation between the Armorican and Perunica sequences.

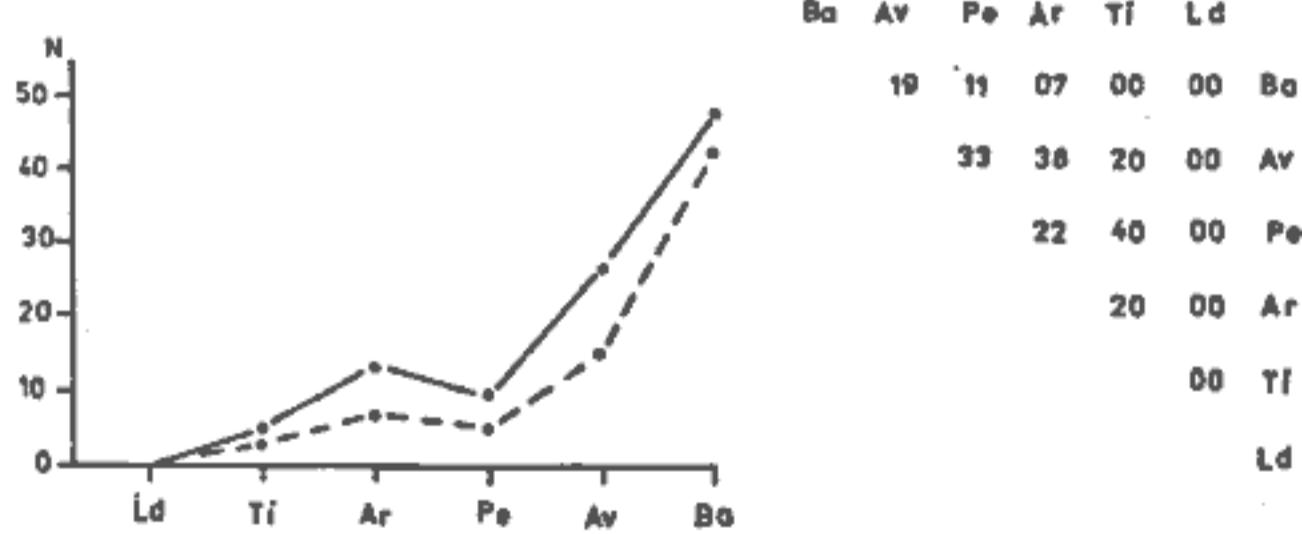
The Dobrotivá Series of Perunica is similar to that of Armorica in containing the both basic lithofacies, i.e. the deeper-water black shales and the sandstones (Skalka Quartzite in the Prague Basin). In central part of the Prague Basin (between Ejovice, Mýto and Kařezek), the anoxic environment of black shales crossed the Llanvirn/Dobrotivá boundary to reach the top of the latter series. The sessile benthos was extremely poor in black shales; vagrant and necto-benthic elements were confined only to a few localities in shallower parts of the Prague Basin, whereas the deeper areas have yielded only poorly diversified associations of planktic (graptolites, phyllocardid crustaceans) and epiplanktic elements such as *Paterula*, *Benignites*, *Brandysia*, and miomerid trilobites. The epiplanktic colonies settled probably large, drifted stems of *Krejciella putzkeri* which, due to the presence of spirally arranged spindle-shaped scars, was assigned by Obrhel (1968) to the Lycophyta (?).

Microphytoplankton is abundant but poorly preserved; Vavrdová (1966) recorded the acritarchs of the genera *Veryhachium*, *Baltisphaeridium*, *Leiosphaeridia*, *Leiosphaera* and *Cymatiogalea*. According to her (1986), the most characteristic species in the Dobrotivá Series are *Stellechinatum celestum* and *Orthosphaeridium ternatum*. Significant chitinozoans are *Conochitina communis*, *C. tuba*, *Cyathochitina campanulaeformis*, *Lagenochitina baltica*; the genera *Desmochitina*, *Pterochitina* and *Sphaerochitina* are also included in the black shales of the Dobrotivá Series.

The sandstones (Skalka Quartzite) are confined to marginal segments of the Prague Basin; on the Prague territory and in East Bohemia, they also reach the deeper parts of the basin. The intertidal and shallow subtidal environment is apparent from the presence of the *Tigillites* Community; body fossils are extremely rare in the Skalka Quartzite (*Tissintia*, *Tafilaltia*).

13. Brachiopod assemblages in the Dobrotivá (about the Llandeilo).

Graphs showing decreasing number of genera from the warm-temperature zone toward the circumpolar sphere, and the coefficients of association between 6 regions investigated (explanation: see text-fig. 4).



Many genera of bivalves, gastropods, echinoderms, and trilobites, recorded in the Llanvirn (Šárka Formation) of Perunica, appeared again in the black shales of the Dobrotivá. On the other hand, the articulate brachiopods *Eodalmanella* and *Euorthisina*, which were abundant in the Llanvirn, did not re-appear in the Dobrotivá, whereas *Benignites* and *Brandysia* inhabited the Prague Basin for the first time. Also the polymerid trilobites *Areia* (*Turantyx*), *Dindymene*, *Dionidella*, *Eccoptochile*, *Eccoptochiloïdes*, *Emmrichops*, *Heterocyclopype*, *Nankinolithus*, *Placoparia* (*Coplacoparia*), *Zeliszkella* a.o. appeared in the Prague Basin for the first time in the Dobrotivá Series.

When comparing Perunica and Baltica, we have to point to an absolute difference in benthic and nekto-benthic associations, because no brachiopod and trilobite genera are in common to both the regions. This fact bears witness that the Tornquist's Sea functioned as an effective barrier at that time (probably its surface currents were even stronger than in the Llanvirn). By contrast to the Llanvirn, the migration of invertebrates between Avalonia and Perunica was rather restricted; common elements to both the regions are *Tissintia* of articulate brachiopods, and *Bergamia*, *Degamella*, *Emmrichops*, *Nobiliasaphus*, *Placoparia* (*Coplacoparia*), and *Zeliszkella* of polymerid trilobites. On the other hand, the faunal relation between Perunica and Armorica increased considerably as shown by the presence of *Colpocoryphe*, *Dionide*, *Eccoptochile*, *Eccoptochiloïdes*, *Ectillaenus*, *Eoharpes*, *Nobiliasaphus*, *Parabarrandia*, *Placoparia* (*Coplacoparia*), *Prionocheilus*, *Selenopeltis*, *Urachilas*, and *Zeliszkella* in both the regions. Interesting matter of Perunica is the absence of *Neseuretus* which is considered as an index trilobite of the high-latitude environment of North Africa and Armorica during the Llanvirn and Dobrotivá.

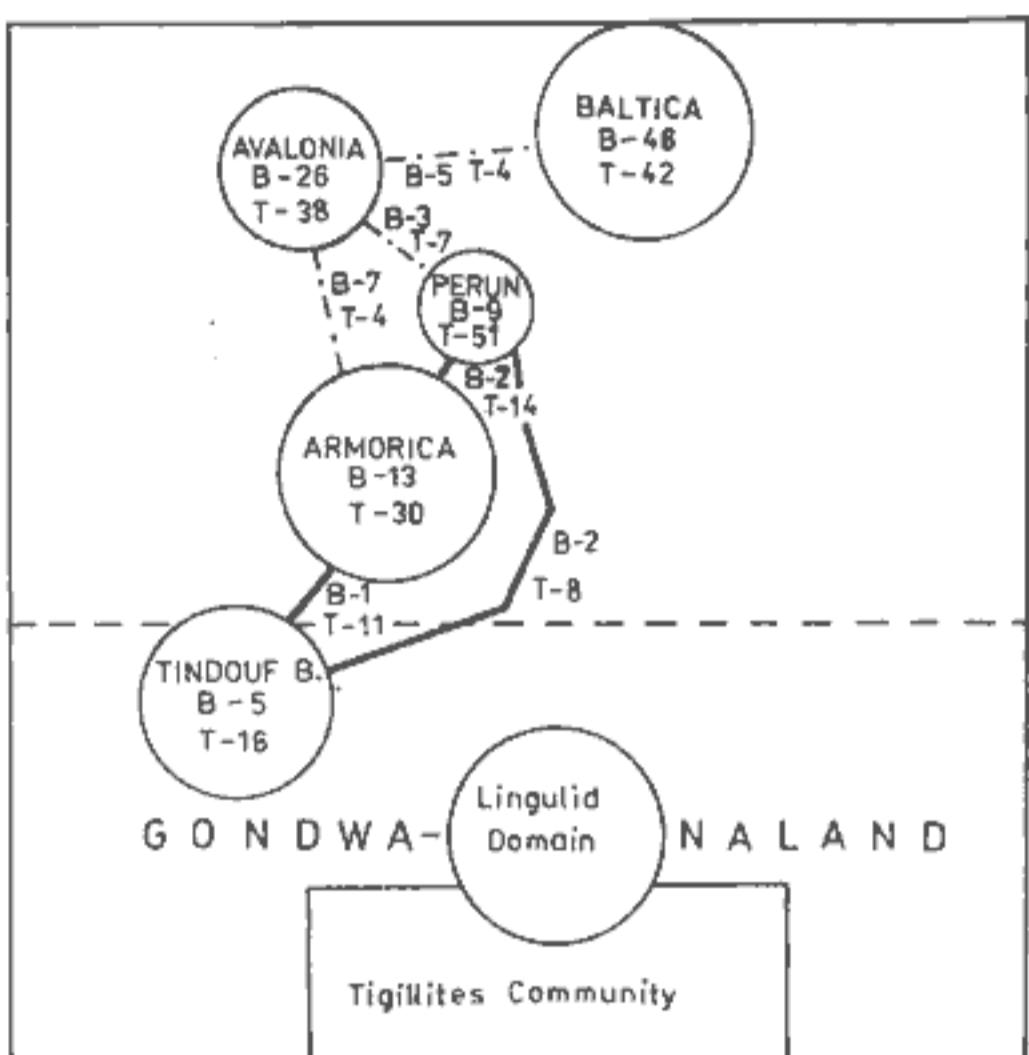
The Bohemian-type faunas decreased in diversity toward the circumpolar sphere; in the Tindouf Basin (Gondwana), they were represented by few brachiopods and trilobites: *Tafilaltia*, *Tissintia*, *Colpocoryphe*, *Degamella*, *Eccoptochile*, *Ectillaenus*, *Nobiliasaphus*?, *Placoparia*, *Selenopeltis*, and *Zeliszkella*. Owing to a pronounced cold-water environment, they are missing altogether in the Ghadamis and Murzúq Basins (Tunisia, Libya).

14. Trilobite assemblages in the Dobrotivá (about the Llandeilo).

Graphs showing decreasing number of genera from the warm-temperature zone toward the circumpolar sphere, and the coefficients of association between 6 regions investigated (explanation: see text-fig. 4).

Data used for palaeogeographic reconstruction of the Dobrotivá Perunica (Prague Basin). Brachiopoda - *Aegiromena*, *Benignites*, *Brandysia*, *Leptobolus*, *Paterula*, "Ptychopeltis", *Rafanoglossa*, *Tafilaltia*, *Tissintia* (Havlíček 1977, 1982)

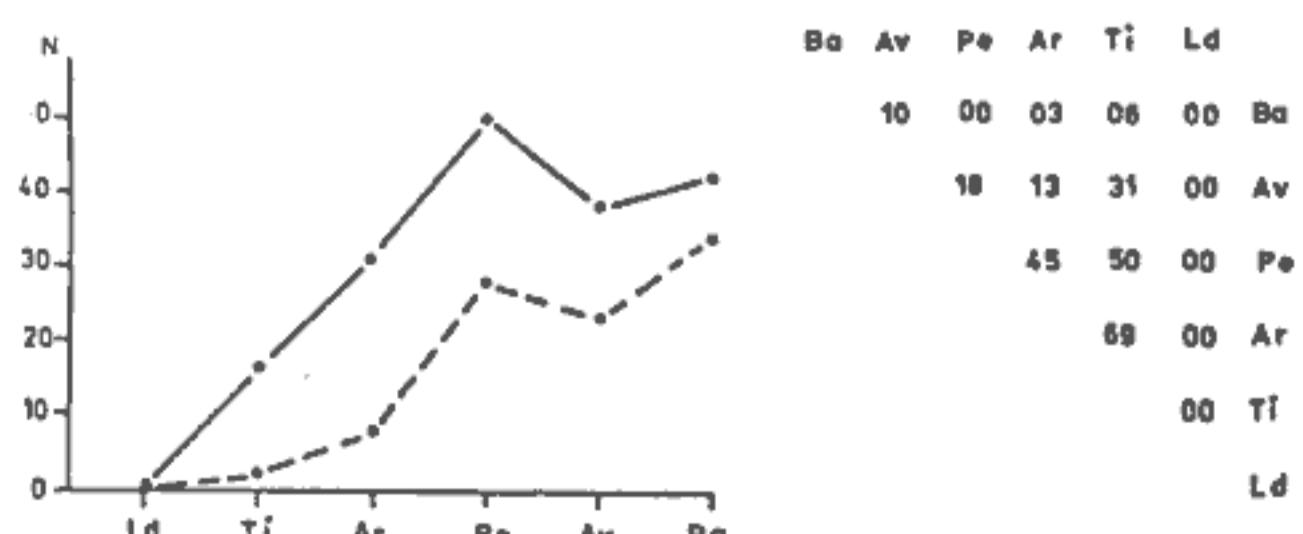
Trilobita - *Areia* (*Turantyx*), *Bergamia*, *Bohemaspis*, *Bohemilla*, *Bohemolichas*, *Brandysops*, *Colpocoryphe*, *Corrugatagnostus*, *Cyclopyge*, *Degamella*, *Dindymene*, *Dionide*, *Dionidella*, *Eccoptochile*, *Eccoptochiloïdes*, *Ectillaenus*, *Ellipsotaphrus*, *Emmrichops*, *Eoharpes*, *Gamops*, *Geragnostella*, *Girvanopyge*, *Heterocyclopype*, *Kodymaspis*, *Lehua*, *Liaignostus*, *Marrolithus*, *Microparia*, *Nankinolithus*, *Nobiliasaphus*, *Ormathops*, *Parabarrandia*, *Pateraspis*, *Petrbokia*, *Phaseolops*, *Placoparia* (*Coplacoparia*), *P.* (*Placoparia*), *Pricyclopype*, *Prionocheilus*,



15. Relation of separate plates and microplates in the Dobrotivá (about the Llandeilo); based on the brachiopod (B) and trilobite (T) assemblages (explanation: see text-fig. 6).

Raphiophorus, *Raymondaspis*, *Sarkia*, *Segmentagnostus*, *Selenopeltis*, *Shumardia* (*Shumardoella*), *Sphaeragnostus*, *Trinucleoides*, *Uralichas*, *Zbriovia*, *Zeliszkella* (*Mytocephala*), *Z.* (*Zeliszkella*) (Pek & Vaněk 1989).

Baltica (Uhaku Formation). Brachiopoda - *Apatorthis*, *Bilobia*, *Christinia*, *Clitambonites*, *Conotreta*, *Crennorthis*, *Dalmanella*?, *Ectenoglossa*, *Eoconulus*, *Eosiphonotreta*, *Estlandia*, *Glossorthis*, *Kjaeromena*, *Kjerulfina*, *Kullervo*, *Ladogiella*, *Leptaena* (including *Estonomena* and



Septomena, *Leptelloidea*, *Leptestia*, *Leptoptillum*, *Oepikina*, *Orbiculoides*, *Palaeostrophomena*, *Paterula*, *Platystrophia*, *Plectambonites*, *Polyambonites*, *Scaphelasma*, *Siphonotreta*, *Sowerbyella* (*Sowerbyella*), *S. (Viruella)* (Alichova 1953; Röömusoks 1963, 1989; Hiots 1968). Further genera: *Acanthambonia*, *Aktassia*, *Biernatia*, *Cyrtometopella*, *Dictyonites*, *Ephippelasma*, *Myotreta*, *Numericona*, *Nushbiella*, *Physotreta*, *Pseudolingula*, *Rowellella*, *Spinilingula*, *Spondylotreta*, *Torynelasma* (Sweden; Holmer 1989).

Trilobita (Norway, Sweden, Baltic regions) - *Ampyx*, *Arthrorhachis*, *Asaphus* (*Asaphus*), *A. (Neoasaphus)*, *A. (Subasaphus)*, *Botrioides*, *Bronteopsis*, *Carolinites*, *Chasmops*, *Cybelurus*, *Cyrtometopella*, *Cyrtometopus*, *Geragnostus*, *Gravicalymene*, *Illaenus*, *Megistaspis* (*Heraspis*), *M. (Megistaspidella)*, *Metopolichas*, *Nileus*, *Niobe*, *Ogmasaphus*, *Ogygiocaris*, *Panderia*, *Phillipsinella*, *Plectasaphus*, *Pliomera*, *Primaspis*, *Pseudoasaphus* (*Pseudoasaphoides*), *Pseudobasilicus*, *Pseudomegalaspis*, *Pseudosphaerexochus*, *Pterygometopus*, *Reedolithus*, *Reraspis*, *Robergia*, *Scotoharpes*, *Sculptaspis*, *Sculptella*, *Stheneroptychus*, *Telephina* (*Telephina*), *T. (Telephops)*, *Turgicephalus* (Balašova 1976; Wandås 1984; Nikolaisen 1963, 1965, 1982).

Armorica (Armorian Massif, Iberian peninsula). Brachiopoda - *Aegiomena*, *Apollonorthis*, *Dalmanella*, *Drabovia*, *Eorhipidomella*, *Gelidorthis*, *Heterorthina*, *Heterorthis*, *Horderleyella*, *Howellites*, *Schizocrania*, *Tazzarinia*, *Tissintia* (Mitchell 1974; Mélou 1975, 1976; Gutierrez-Marco et al. 1984; Villas 1985).

Trilobita - *Calymenella*, *Colpocoryphe*, *Crozonaspis*, *Dionide*, *Eccoptochile*, *Eccoptochiloidea*, *Ectillaenus*, *Eodalmanitina*, *Eoharpes*, *Eohomalomotus*, *Guichenia*, *Iberocoryphe*, *Kerfornella*, *Kloucekia*, *Marrolithus*, *Morgatia*, *Neseuretus*, *Nobiliasaphus*, *Panderia*, *Parabarrandia*, *Pateraspis*, *Phacopidina*, *Placoparia* (*Coplacoparia*), *Plaesiacomia*, *Prionocheilus*, *Salterocoryphe*, *Selenopeltis*, *Uralichas*, *Valongia*, *Zeliszkella* (Henry 1980; Rábano 1984; Pillet 1989, 1990).

Gondwana (Tindouf Basin, Premier Bani Formation). Brachiopoda - *Atlantida*, *Orthambonites*, *Paterorthis*, *Tafilaltia*, *Tissintia* (Havlíček 1971).

Trilobita - *Colpocoryphe*, *Crozonaspis*, *Dalmanitina*, *Degamella*, *Dreyfussina*, *Eccoptochile*, *Ectillaenus*, *Eohomalotonotus*, *Kloucekia*, *Marrolithus*, *Neseuretus*, *Ogygiocaris*, *Placoparia*, *Plaesiacomia*, *Selenopeltis*, *Zeliszkella* (Destombes 1966, 1967a, 1972). In the Ghadamis and Murzúq Basins, no determinable body fossils have been found.

Avalonia (Shelf Inlier, Meadowtown and Rorrington Beds). Brachiopoda - *Bicuspsina*, *Dalmanella*, *Gelidorthis*, *Glyptorthis*, *Horderleyella*, *Kullervo*, *Murinella*, *Oxoplecia*, *Palaeoglossa*, *Paterula*, *Rafanoglossa* (= *Pseudolingula* in Williams 1974), *Rafinesquina*, *Schizocrania*, *Schizotreta*, *Skenidioidea*, *Sowerbyella*, *Tazzarinia*, *Tissintia* (Williams 1974). Further genera: *Ateleasma*, *Corineorthis*, *Heterorthina*, *Mcewanella*, *Platystrophia*, *Rostricellula*, *Salopia*,

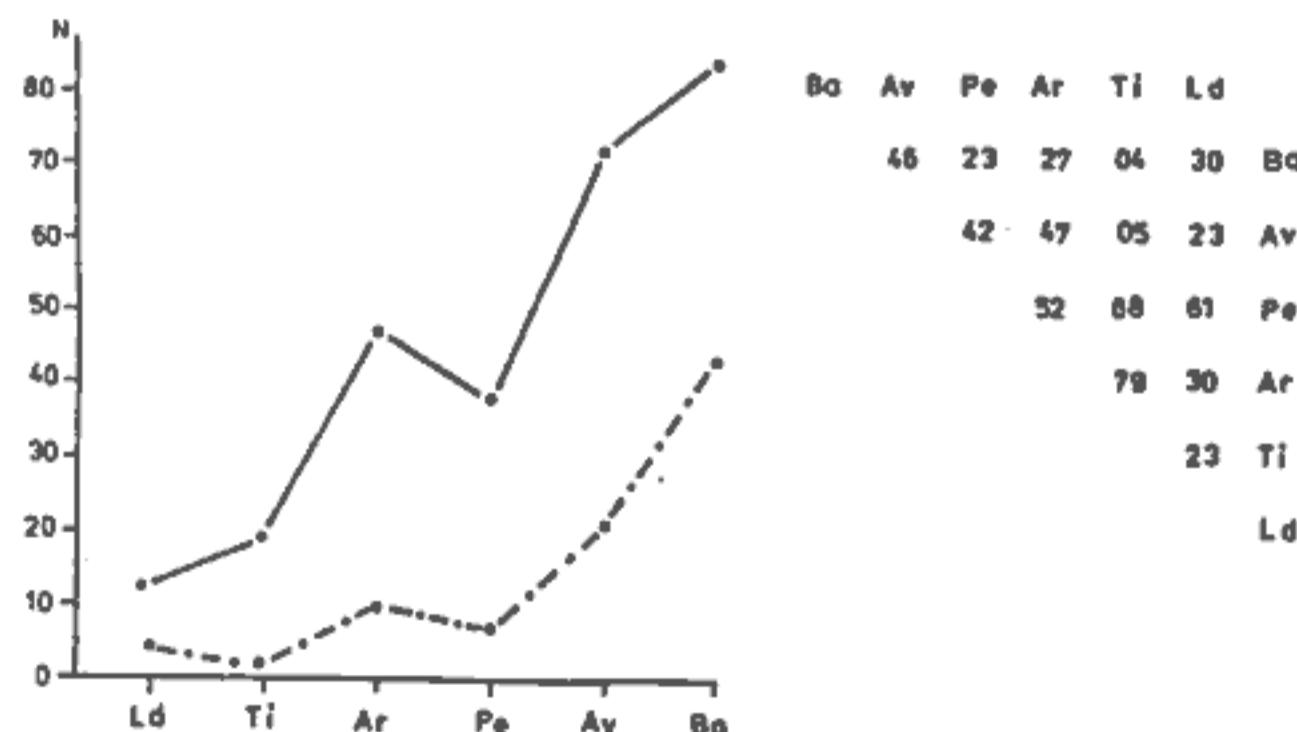
Schalidomorthis (Cornwall; Bassett 1981; North Wales: MacGregor 1961).

Trilobita (England, Wales) - *Atractopyge*, *Barrandia*, *Basilicus*, *Bergamia*, *Bettonia*, *Birmanites*, *Botrioides*, *Cnemidopyge*, *Crozonaspis*, *Decoroproetus*, *Emmrichops*, *Failleana*, *Flexicalymene*, *Geragnostus*, *Homalopteron*, *Kloucekia*, *Lloydolithus*, *Marrolithoides*, *Marrolithus*, *Metopolichas*, *Neseuretus*, *Nobiliasaphus*, *Ogyginus*, *Ogygiocarella*, *Parabathycheilus* (= *Bathycheilus* in Sadler 1974), *Placoparia*, *Placoparina*, *Platycalymene*, *Pricyclopyge*, *Primaspis*, *Protolloydolithus*, *Rorringtonia*, *Segmentagnostus*, *Sphaeragnostus*, *Spirantyx*, *Telaeomarrolithus*, *Trinucleus*, *Whittardolithus* (Bates 1968; Hughes 1969, 1979; Hughes et al. 1975; Sadler 1974; Thomas et al. 1984).

Beroun

The Beroun Series is a further link in the Ordovician history; in the Mediterranean Province, it is an epoch of a crustal instability as shown by various rates of uplift and sinking in separate minor segments, presence of gaps in sedimentation, and higher volcanic activity (Hammann et al. 1982). Further, the Beroun is a time of higher sea level stand and, consequently, a time of a common occurrence of typical black shales forming sequences up to several hundreds of metres thick (e.g. in the Prague Basin), and containing poor to no benthic biotas. On the other hand, the richly diversified *Aegiomena-Drabovia* fauna appeared suddenly in shallower parts of the former basins in the lowermost Beroun to persist to the top of the series. The Mediterranean *Aegiomena-Drabovia* fauna (defined by Havlíček 1989) is roughly coeval with a significant diversification of the sessile benthos, recorded in the British Caradoc (Leggett et al. 1981).

Havlíček and Marek (1973) suggested the name Beroun Series for a thick sequence of dark to black shales, pyroclastics, sandstones and subordinate sedimentary iron ores bearing in latter two types of rocks the distinctive *Aegiomena-Drabovia* fauna dominated by articulate brachiopods *Aegiomena*, *Drabovia*, *Drabovinella*, *Gelidorthis*, *Heterorthina*, *Heterorthis*, and *Hirnantia*. The Beroun Series is approximately comparable to the Caradoc of the British scale; its lower and upper limits, however, cannot be precisely correlated with the



16. Brachiopod assemblages in the Beroun (about the Caradoc). Graphs showing decreasing number of genera from the warm-temperature zone toward the circumpolar sphere, and the coefficients of association between 6 regions investigated (explanation: see text-fig. 4).

Llandeilo/Caradoc and Caradoc/Ashgill boundaries in Great Britain because of different faunal content and paucity of graptolites in Bohemia. In the British Isles, both the lower and upper boundaries of the Caradoc have been drawn within the graptolite zones (i.e. within the *Nemagraptus gracilis* and *Pleurograptus linearis* Zones; Williams et al. 1972). This procedure is the main handicap in any attempt of a precise correlation of the British Caradoc to the sequences of other regions.

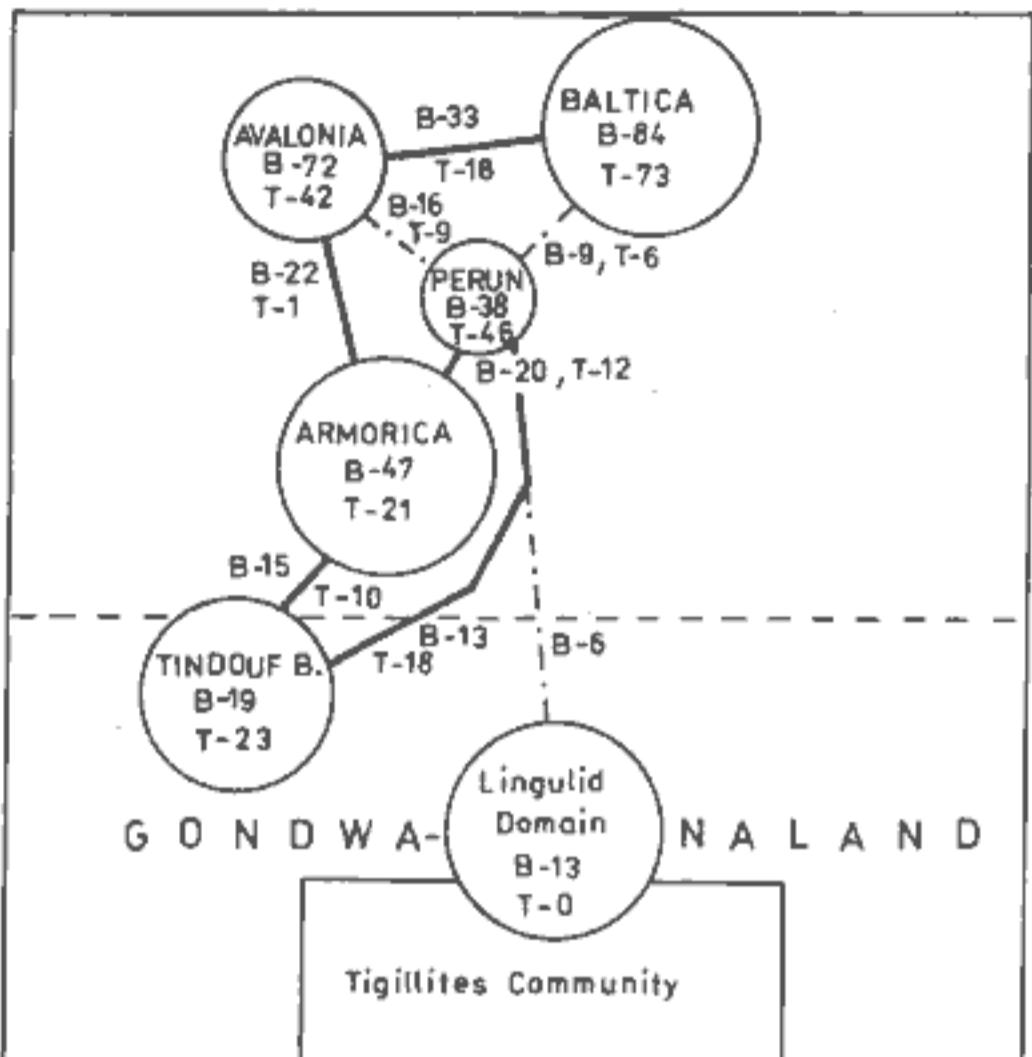
In the British scale, the Caradoc is subdivided into 7 stages (Costonian, Harnagian, Soudleyan, Longvillian, Marshbrookian, Actonian, Onnian) which all present local stratigraphic units not applicable in the Mediterranean Province.

In Perunica, the Beroun Series is best developed in the Prague Basin; further, it has also been proved in East Bohemia, Rožmitál Graben (in both regions only black-shale lithofacies), Thuringia (upper part of the Gräfenthal Group), and in Hessen (Andreas Quartzite); the Bohemian-type trilobites *Cyclopyge*, *Dalmanitina*, *Dionide*, *Prionocheilus*, *Stenopareia*, and *Zeliszkella*, and many bivalves were also found in Belgium south of the Brabant Massif (Sart-Bernard Formation; Maillieux 1939).

In the Prague Basin, the Beroun Series is a thick clastic sequence with subordinate lenses of sedimentary iron ores; the black shales, containing about 1 per cent of organic carbon (Kukal 1963) and finely disseminated pyrite, form either rather thick sequences (e.g. the Libeň, Vinice, and Bohdalec Shales), or variably thick intercalations within the sandy sediments. The shales contain poorly diversified pelagic biotas (*Paterula* Communities; Havlíček & Vaněk 1990). The benthic fauna is either absent in shales or it has been encountered near the rising zones within the basin (Havlíček 1981; Havlíček & Vaněk 1990).

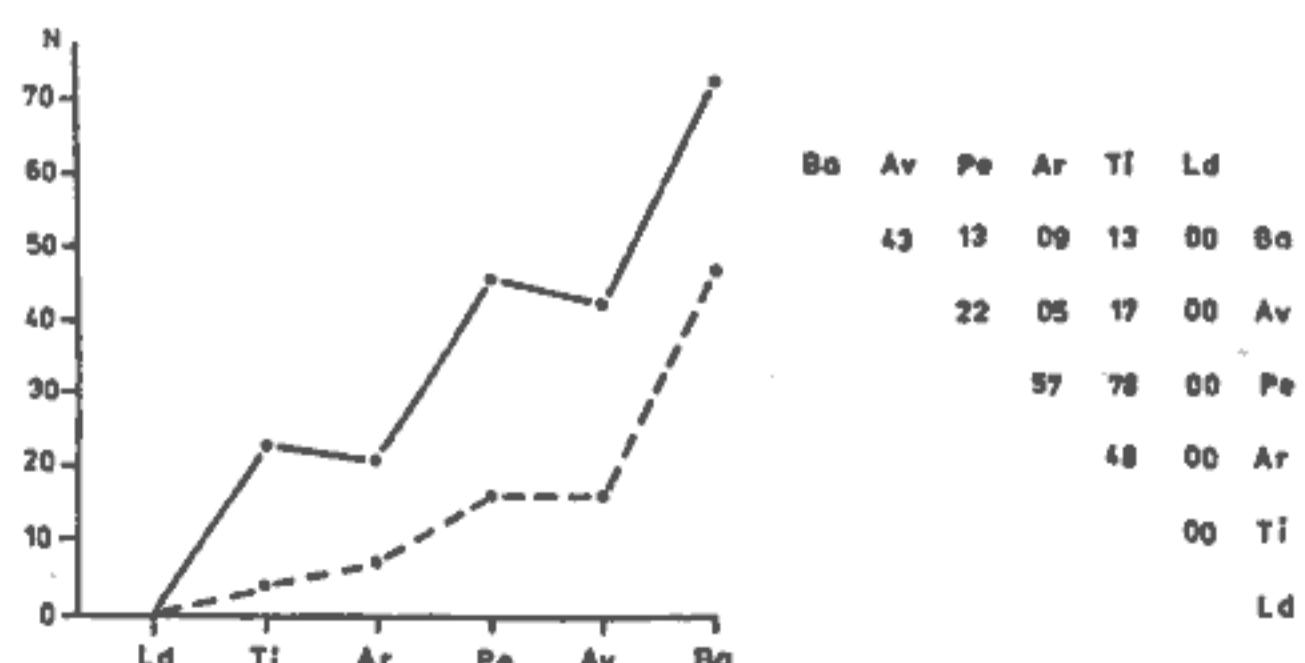
No graptolites have so far been found in shales of the lower Beroun. The middle Beroun has yielded *Climacograptus cf. wilsoni*, *Glyptograptus trubinensis trubinensis*, *Rectograptus truncatus* in the Vinice Formation, and *Climacograptus cf. wilsoni*,

Glyptograptus trubinensis extensus, *G. insculptus*, *Rectograptus truncatus*, and *R. bohemicus* in the Záhořany Formation. The following graptolites come from the upper Beroun (Bohdalec Formation): *Diplograptus vulgaris*, *Rectograptus bohdalecensis*, *R. linguitheca*, *Orthograptus spinosus*, and from the lower part of the Bohdalec Formation also *Dicranograptus cf. clingani* (Havlíček & Vaněk 1966).



18. Relation of separate plates and microplates in the Beroun (about the Caradoc); based on the brachiopod (B) and trilobite (T) assemblages (explanation: see text-fig. 6).

Microphytoplankton is richly diversified in the Beroun; all available data were summarized by Vavrdová (1974, 1986); according to her, the Beroun is characterized by disappearance of diacrodian morphotypes, whilst other groups (*Polygonomorphidae*, *Acanthomorphidae* a.o.) are still frequent. Typical species in the Prague Basin (mainly



17. Trilobite assemblages in the Beroun (about the Caradoc). Graphs showing decreasing number of genera from the warm-temperature zone toward the circumpolar sphere, and the coefficients of association between 6 regions investigated (explanation: see text-fig. 4).

in the Letná, Zahořany and Bohdalec Formations) are *Cheleutochroa gymnobrachiata* and *Multiplicisphaeridium irregulare*.

All brachiopods of the *Aegiromena-Drabovia* fauna appeared in Bohemia for the first time; some of them, however, are immigrants from Armorica and Avalonia, where they were recorded in the Dobrotivá (Llandeilo), for example *Aegiromena* and *Heterorthina*. The index Berounian genera are *Svobodaina*, *Drabovia*, *Drabovinella*, all confined to shallow-water environments. The deeper-water black shales contain mainly a minute pseudoplanktic brachiopod *Paterula bohemica*, in the upper Beroun accompanied by *Anx ater*, *Karlicium patens*, *Aegiromena descendens*, and *Sericoidaea homolensis*.

The trilobites are frequent in the Prague Basin; several genera cross the Dobrotivá/Beroun boundary (e.g. *Eccoptochile*, *Eccoptochiloïdes*, *Platycoryphe*, *Prionocheilus*, *Selenopeltis*) or they appear in the Beroun for the first time [e.g. *Actinopeltis*, *Calymenella*, *Cekovia*, *Dalmanitina*, *Deanaspis*, *Eudolatites*, *Onnia*, *Placoparia* (*Hawleia*)]. Endemic trilobites are very rare (*Chlustinia*). A few "typical" Dobrotivian trilobites survive to the lowermost Beroun: *Ectillaenus*, *Placoparia* (*Coplacoparia*). Several trilobites invaded the Prague Basin in the middle or even upper Beroun; a significant immigrant of Mediterranean origin (France, Spain, Morocco) is *Phacopidina*; even more interesting are the newcomers in the upper Beroun (Bohdalec Formation); they indicate the re-opening of migration routes from Baltica and Avalonia to the Prague Basin (e.g. *Lonchodus*, *Raphiophorus*, *Sculptaspis*).

The close faunal and palaeogeographic relation between Perunica and Armorica persisted from the Dobrotivá to the Beroun as indicated by many brachiopod and trilobite genera in common to both the regions. In the Armorican Massif, the La Sangsurière, Kermeur, and Riadan Formations are of Beroun age; also the uppermost part of the Postolonnec Formation has been assigned to the lowermost Caradoc (Beroun) on palaeontological grounds. In the Iberian peninsula, the "Bancos mixtos", "Shales with *Onnia*" (Spain), Louredo Formation and the lower part of the Porto do Santa Anna Formation (Buçaco area, Portugal) are of Beroun age. A common feature of the Perunican and Armorican lower Beroun is the presence of *Colpocoryphe grandis*; a precise correlation of the base of the Beroun in Perunica and Armorica needs further investigation.

The upper Beroun of the Montagne Noire, Eastern Iberian Chains, and Sardinia differs considerably from that of Perunica in an influx of many warmer-water benthic elements to give rise to mixed assemblages consisting of original "cold-water" *Aegiromena-Drabovia* stocks as well as of new warmer-water immigrants from Avalonia, supplemented by several North African genera (Havlíček 1989). These assemblages, dominated by

Nicolella, *Dolerorthis*, *Iberomena*, and *Eoanastrophia* are moderately diachronous as they are of middle-upper Berounian age in the Carnic Alps (Havlíček et al. 1987) whereas they cross the Beroun/Kralodvor boundary in Sardinia and the Iberian Chains (Villas 1985, Havlíček et al. 1987). Leone et al. (1991) suppose that the Caradoc/Ashgill boundary in Sardinia lies within the Portixeddu Fm., although its uppermost part contains *Nobiliasaphus cf. kumatora* and *Longvillia*, both indicating a Berounian age. Also in the Montagne Noire, the "mixed" brachiopod assemblages were confined to the Beroun/Kralodvor boundary; the upper part of the fossiliferous layers should be transferred to the Kralodvor (Ashgill) due to the presence of *Amorphognathus ordovicicus* (Babin, Feist, Mélou & Paris 1988). The invasion of Avalonian-type brachiopods into Armorica indicates a phase of a marked increase of temperature which was an impuls for the warmer-water fauna to colonize the extensive, rather stable shallow-water plains in South Europe. It is worth to note that these Avalonian-type elements neither invaded Perunica nor inhabited the Gondwanan epicratonic basins. Further, the significant migration has shown that the Rheic Sea could not preclude the interchange of benthic fauna between Armorica and Avalonia in the upper Beroun and lower Kralodvor.

Owing to its position in the circumpolar sphere, the Tindouf Basin (Gondwana) was never colonized by any warmer-water elements. By contrast to Armorica, its sessile benthos retained its "pure Bohemian" character dominated by the Bohemian-type genera *Aegiromena*, *Drabovia*, *Drabovinella*, *Gelidorthis*, *Heterorthina* a.o. In the Gondwanan basins, the diversity of fauna gradually decreases towards the Pole. The Ghadamis and Illizi Basins (Libya, Tunisia, Algeria) are mostly "lingulid domains" with a few articulate brachiopods such as *Aegiromena* and *Onnizetina* (both epiplanktic?, Djeffara Formation; Massa, Havlíček & Bonnefous 1977). Even cooler environment was recorded in the Murzúq Basin (Libya) where the glacio-marine sediments (shales with frequent blocks and pebbles of pre-Ordovician rocks) of the Meléz Chograne Formation have yielded "*Aratanea*", *Drabovinella*, *Rafinesquina*, rather common inarticulate brachiopods, rare trilobites (not determined) and other benthic fauna (Havlíček & Massa 1973).

Data used for palaeogeographic reconstruction of the Beroun Perunica (Prague Basin). Brachiopoda - *Aegiromena*, *Anx*, *Bicuspidaria*, *Blyskavomena*, *Christenopora*, *Cilinella*, *Drabodiscina*, *Drabovia*, *Drabovinella*, *Fezzanoglossa?*, *Gelidorthis*, *Heterorthina*, *Heterorthina*, *Himantia*, *Horderleyella*, *Howellites*, *Jezercia*, *Marionites*, *Onnia*, *Onnizetina*, *Orbiculoides*, *Paterula*, *Petrocrania*, *Plectoglossa*, *Ptychopeltis*, *Rafinesquina*, *Rostricellula*, *Saukrodictya*, *Schizotretula*, *Svobodaina*, *Tafilaltia*, *Tazzarinia*, *Tissintia*, "Torynelasma", *Trematopora*, *Triplegia*. Further genera in the upper Beroun (Bohdalec Formation) - *Karlicium*, *Sericoidaea* (Havlíček 1977). Trilobita - *Actinopeltis*, *Arthrorhachis*, *Birmanites*, *Bohemites*, *Calymenella*, *Cekovia*, *Chlustinia*, *Colpocoryphe*, *Cyclopyge*.

Dalmanitina, *Deanaspis*, *Declivolithus*, *Dindymene*, *Dionide*, *Eccoptochile*, *Eccoptochiloides*, *Ectillaenus*, *Ellipsotaphrus*, *Eodindymene*, *Eudolatites* (*Banilatites*), *E. (Destombesites)*, *E. (Eudolatites)*, *Flexicalymene*, *Girvanopyge*, *Heterocyclophe*, *Kloucekia*, *Lonchodus*, *Marrolithus*, *Nobiliasaphus*, *Onnia*, *Phacopidina*, *Placoparia* (*Hawleia*), *Plaesiacomia*, *Platycoryphe*, *Primaspis*, *Prionocheilus*, *Raphiophorus*, *Sculptaspis* (recently found in the Bohdalec Shale), *Selenopeltis*, *Sokhretia*, *Stenopareia*, *Ulugtella*, *Vysocania*, *Zbirovia*, *Zeliszkella* (*Mirops*), *Z. (Zeliszkella)* (Pek & Vaněk 1989).

Baltica (Baltic regions, Idavere to Nabala Formations). Brachiopoda - *Actinomena*, *Alichovia*, *Apatorthis*, *Bilobia*, *Boreadorthis*, *Cliftonia*, *Clinambon*, *Clitambonites*, *Cremnorthis*, *Cyrtonotella*, *Dalmanella*, *Ectenoglossa*, *Eoplectodonta*, *Eorhipidomella*, *Epitomyonia*, *Estandia*, *Glossorthis*, *Glyptorthis*, *Hesperorthis*, *Holledahlina*, *Horderleyella*, *Howellites*, *Ilmarinia*, *Kiaeromena*, *Kjerulfina*, *Kullervo*, *Laticrura*, *Leptaena* (including *Astamena*, *Kurnamena*, *Septomena*, *Simileptaena*), *Leptelloidea*, *Lingulops*, *Microtrypa*, *Mjoesina*, *Multispinula*, *Nicolella*, *Oanduporella*, *Oepikina*, *Onniella*, *Orthisocrania*, *Paterula*, *Paucicrura*, *Philhedra*, *Platystrophia*, *Porambonites*, *Pseudolingula*, *Pseudostrophomena*, *Rafinesquina*, *Reuschella*, *Rhactorthis*, *Rostricellula*, *Sampo*, *Saukrodictya*, *Schizotreta*, *Septorthis*, *Siphonotreta*, *Sowerbyella*, *Strophomena*, *Thaerodonta*, *Triplesia*, *Vellamo*, *Westonia*, *Wysogorskiella* (Öpik 1930, 1933; Alichova 1953, 1969; Röömusoks 1963, 1989; Hints 1968, 1971, 1973, 1975, 1979; Gorjanskij 1969). Further brachiopod genera in Norway: *Alwynella*, *Chonetidea*, *Christiania*, *Grorudia*, *Hedstroemina*, *Orbiculoides*, *Oxoplecia*, *Parastrophinella*, *Plectorthis* (4α-4β Zones, Spjeldnaes 1957; Upper Chasmops Shale, Owen & Harper 1982). Further brachiopods in Sweden: *Acanthambonia*, *Acrotretella*, *Biernatia*, *Cyrtonotella*, *Eoconulus*, *Ephippelasma*, *Hisingerella*, *Myotreta*, *Nushbiella*, *Rhinotreta*, *Scaphelasma*, *Spondylotreta*, *Tetraodontella*, *Veliseptum* (Jaanusson 1962; Holmer 1986, 1989).

Trilobita (mostly Norway and Sweden) - *Acidaspis*, *Amphilichas*, *Amphitryon*, *Ampyxella*, *Ampyxina*, *Apianurus*, *Arthorhachis*, *Asaphus* (*Postasaphus*), *Atractopyge*, *Bolbochasmops*, *Botrioides*, *Broeggerolithus*, *Calyptaulax*, *Conolichas*, *Cyamops*, *Cybelella*, *Cyrtometopella*, *Decoroproetus* (*Decoroproetus*), *D. (Dalarnepeletis)*, *Diacanthaspis*, *Dimeropyge*, *Encrinurus*, *Eukosovopeltis*, *Estoniites*, *Estoniops*, *Flexicalymene*, *Frogaspis*, *Gravicalymene*, *Harpidella*, *Hemiargus*, *Leningradites*, *Lichas*, *Lonchodus*, *Metopolichas*, *Miraspis*, *Nieszkowskia* (*Ainoa*), *N. (Nieszkowskia)*, *Ogmasaphus*, *Ogygiocaris*, *Onnicalymene*, *Otarion* (*Conoparia*), *Panarchaeogonus*, *Panderia*, *Paraceraurus*, *Paraharpes*, *Phillipsinella*, *Platylichas*, *Primaspis*, *Prionocheilus*, *Pseudobasilicus*, *Pseudobasiliella*, *Pseudosphaerexochus*, *Raymondella*, *Reacalymene*, *Reedolithus*, *Remopleurella*, *Remopleurides*, *Reraspis*, *Roringtonia*, *Scopolochasmops*, *Sculptaspis*, *Sphaerocoryphe* (*Hemisphaerocoryphe*), *S. (Sphaerocoryphe)*, *Stenopareia*, *Stubblefieldia*, *Telephina* (*Telephina*), *T. (Telephops)*, *Thaemataspis*, *Toxochasmops*, *Tretaspis*, *Triarthrus*, *Viruanaspis*, *Xenasaphus* (Öpik 1937; Thorslund 1940).

Armorica (Armorican Massif: Raguenez Formation; uppermost part of the Postolonne Formation; lower-middle part of the Saint-Germain-sur-Illle Formation; lower part of the Rosan sequence; Portugal: Louredo Formation. Spain: Fombuena Formation and lowermost part of the Calizas de Cistideos Formation, biozone 6a. Further Montagne Noire and Sardinia).

Brachiopoda - *Aegiromena*, *Aegironetes*, *Bicuspsina*, *Chrustenopora*, *Craniops*, *Dalmanella*, *Dolerorthis*, *Drabovia*, *Drabovinella*, *Elliptoglossa*, *Eoanastrophia*, *Eridorthis*, *Gelidorthis*, *Glyptorthis*, *Heterorthina*, *Howellites*, *Iberomena*, *Kozlowskites*, *Leangella*, *Leptaena*, *Leptesiina*, *Longvillia*, *Multicostella*, *Nicolella*, *Nicolorthis*, *Onniella*, *Onnizetina*, *Oxoplecia*, *Paterula*, *Paucicrura*, *Paurorthis*, *Petrocrania*, *Porambonites*, *Portranella?*, *Protomendacella*, *Ptychopleurella*, *Rafinesquina*, *Reuschella*,

Rostricellula, *Saukrodictya*, *Skenidiooides*, *Svobodaina*, *Tafilaltia*, *Tazzarinia*, *Tissintia*, *Triplesia* (Babin & Mélou 1972; Mélou 1975, 1985, 1990; Chauvel, Drot, Pillet & Tamain 1969; Mitchell 1974; Villas 1985; Villas et al. 1987; Havlíček 1981; Havlíček, Kříž & Serpagli 1987).

Trilobita - *Actinopeltis*, *Calymenella*, *Cekovia*, *Chattiaspis*, *Colpocoryphe*, *Crozonaspis*, *Dalmanitina*, *Delgadoa*, *Diacanthaspis*, *Dreyfussina*, *Eccoptochile*, *Eoharpes*, *Eudolatites*, *Iberocoryphe*, *Nobiliasaphus*, *Onnia*, *Phacopidina*, *Plaesiacomia*, *Prionocheilus*, *Scotiella*, *Zetillaenus* (Thadeu 1947; Henry 1980; Rábano 1984).

Gondwana (Tindouf Basin: Lower Ktaoua, Tiouririne, and Rouid Aissa Formations).

Brachiopoda - *Aegiromena*, *Bicuspsina*, *Cliftonia*,

Dalmanella, *Destombesium*, *Drabovia*, *Drabovinella*, *Gelidorthis*,

Heterorthis, *Howellites*, *Irhirea*, *Kiaeromena*, *Onniella*,

Protomendacella, *Rafinesquina*, *Rostricellula*, *Tafilaltia*, *Tazzarinia*,

Triplesia (Havlíček 1971).

Trilobita - *Actinopeltis*, *Calymenella*, *Chattiaspis*, *Colpocoryphe*, *Cryptolithus*, *Cyclopyge*, *Dalmanitina*, *Declivolithus*, *Eccoptochile*, *Eudolatites* (*Banilatites*), *E. (Eudolatites)*, *Flexicalymene*, *Kloucekia*, *Marrolithus*, *Mucronaspis*, *Ormathops*, *Phacopidina*, *Placoparia*, *Plaesiacomia*, *Primaspis*, *Prionocheilus*, *Raymondaspis*, *Selenopeltis* (Destombes 1967, 1972; Hughes, Ingham & Addison 1975).

Gondwana (Lingulid domain, Ghadamis and Murzūq Basins).

Brachiopoda - *Aegiromena*, "Aratanea", *Drabodiscina*, *Drabovinella*,

Fezzanoglossa, *Libyaeglossa*, *Lingulella*, *Onnizetina*, *Orbiculothyris*,

Orbiculoides, *Palaeoglossa*, *Rafinesquina*, "Torynelasma" (Massa,

Havlíček & Bonnefous 1977; Havlíček & Massa 1973).

Avalonia (Caradoc of Wales). Brachiopoda - *Anisopleurella*,

Bancroftina, *Bellimurina*, *Bicuspsina*, *Bystromena*, *Caeroplecta*,

Chonetidea, *Christiania*, *Craniops*, *Cremnorthis*, *Cryptorthis*,

Cyclospira, *Cyrtonotella*, *Dalmanella*, *Dinorthis*, *Dolerorthis*,

Drabovia, *Elliptoglossa*, *Eoplectodonta*, *Furcitella*, *Glossorthis*,

Glyptomena, *Glyptorthis*, *Harknessella*, *Hedstroemina*, *Heterorthina*,

Heterorthis, *Horderleyella*, *Howellites*, *Kiaeromena*, *Kjaerina*,

Kjerulfina, *Kullervo*, *Leptaena*, *Leptesiina*, *Lingulops*, *Longvillia*,

Macrocoelia, *Marionites*, *Nicolella*, *Onniella*, *Orbiculoides*,

Orthambonites, *Orthisocrania*, *Oxoplecia*, *Palaeoglossa*,

Palaeostrophomena, *Parastrophinella*, *Paterula*, *Petrocrania*,

Platystrophia, *Plectorthis*, *Rafinesquina*, *Reuschella*, *Rhactorthis*,

Rostricellula, *Salacorthis*, *Salopia*, *Schizocrania*, *Schizotreta*,

Sericoides, *Skenidiooides*, *Smeathenella*, *Sowerbyella*, *Trematis*,

Triplesia, *Vellamo*, *Whittardia*, *Zygospira* (Dean 1958; Williams 1963,

1974; Hurst 1979). Further genera: *Bilobia*, *Ilmarinia*, *Ptychopleurella* (Anglesey, Nemagraptus gracilis Zone; Bates 1968).

Trilobita - *Amphilichas*, *Ampyx*, *Ampyxella*, *Atractopyge*,

Broeggerolithus, *Brongniartella*, *Calyptaulax*, *Costonia*, *Cybeloides*

(*Paracybeloides*), *Decoroproetus*, *Dindymene*, *Estoniops*,

Flexicalymene, *Gravicalymene*, *Illaenus* (*Parillaenus*), *Lonchodus*,

Marrolithoides, *Marrolithus*, *Ogygiocarella*, *Omnia*, *Onnicalymene*,

Otarion (*Beggaspis*), *Otarozoum*, *Parabasilius*, *Phacopidina*,

Platycalymene, *Platycoryphe*, *Platylichas*, *Primaspis*, *Protobronteus*,

Reacalymene, *Remopleurella*, *Remopleurides*, *Reuscholithus*,

Salterolithus, *Scopolochasmops*, *Smeathenia*, *Spirantyx*,

Telaeomarrolithus, *Toxochasmops*, *Tretaspis*, *Triarthrus* (Dean 1963;

Thomas et al. 1984; Thomas & Holloway 1988).

Kralodvor

The Kralodvor Series differs considerably from the preceding Beroun Series both in lithology and biotas. In the Mediterranean Province, the Beroun/Kralodvor boundary is marked by a disappearance of the widespread black-shale lithofacies which was replaced by sedimentation of greenish mudstones and micritic carbonates. It is worth to note that a similar, roughly

coeval, changeover in lithology has been recorded in the British Isles, where the euxinic lithofacies reached its peak in the uppermost Caradoc (Onnian), whereas the lowermost Ashgill (Pushgillian) was marked by a sudden disappearance of the black-shale lithofacies. According to Leggett et al. (1981), this change in lithology may have been induced by a world-wide eustatic regression during the Ashgill. This idea may be accepted in the western part of the Mediterranean Province where the lower-middle Ashgill (Kralodvor), if present at all, consists of shallow-water, high-energy cystoid limestones; in the Armorican Massif and Iberian peninsula, the Kralodvorian regression is accompanied by frequent gaps in sedimentation (Robardet & Doré 1988).

In Bohemia, although the deeper-water sedimentation still continued, the anoxic environment was replaced by a better-oxygenated soft floor environment since the beginning of the Kralodvor. Presence of ferruginous, oolitic shales at the very base of the Kralodvor bears witness for a further, although weak expansion of the sea in the Prague Basin.

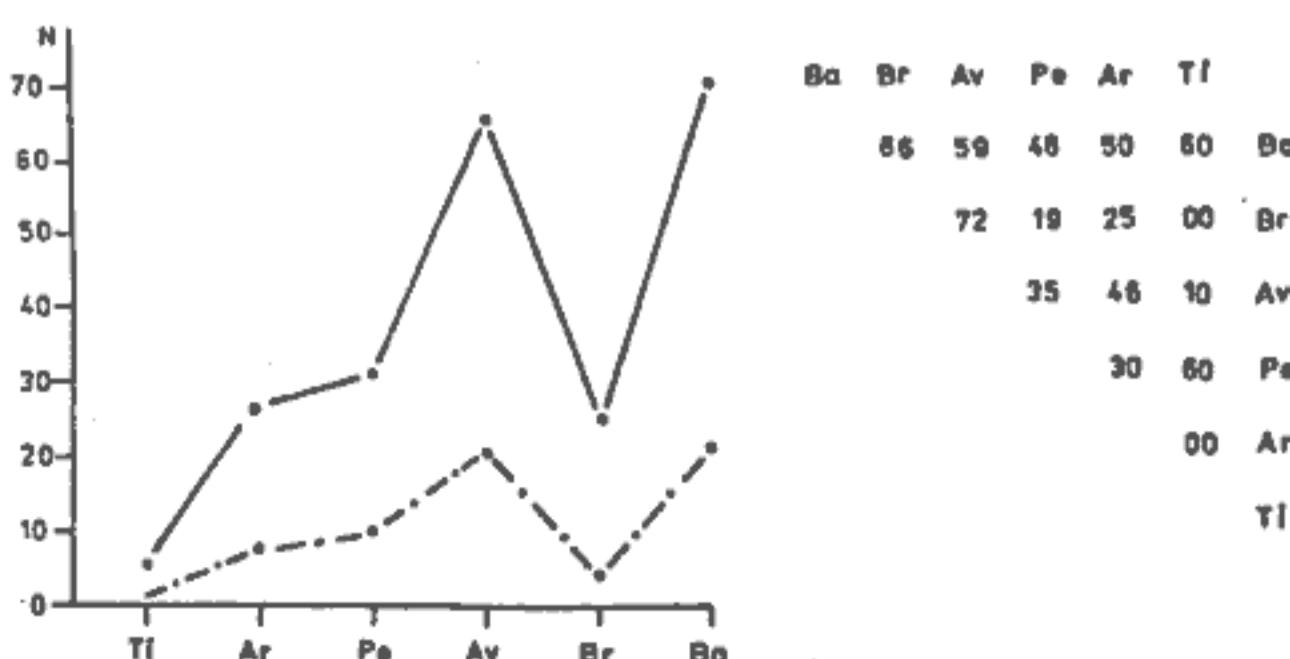
Instead of eustatic regression, a pronounced marine transgression played an important role in the lowermost Kralodvor of the Tindouf Basin, where the upper Ktaoua Formation overlies the massive sandstones of the Rouid Aissa Formation (Destombes 1968, 1971); the transgression is accompanied there by an oolitic ferrolite which is most probably coeval with a similar rock of the very base of the Bohemian Kralodvor.

Another point of view is that of Sheehan (1987) who supposed a gradual intensification of the Late Ordovician glaciation during the Ashgill; according to him, a cold, dense, oxygenated water could sink into the ocean basins from polar regions and, consequently, it could allow the radiation of the *Foliomena* fauna in previously anaerobic regions. However, the absence of glacio-marine sediments in the Gondwanan epicratonic basins, extension of the first warmer-water biotas to South Europe, and appearance of the reefs in Armorica contradict the Sheehan's idea. For this reason, the Kralodvor (about lower-middle Ashgill) is better explained as an epoch with a marked increase of temperature (Havlfček 1989).

The Kralodvor Series was proposed by Havlfček and Marek (1973) for a sequence of greenish mudstones with subordinate intercalations of silty shales and clayey carbonates overlying the black-shale lithofacies of the upper Beroun (Bohdalec Shale); the base of the Kralodvor is locally accentuated by a discontinuous horizon of the oolitic ferruginous shale. The black claystones (Lejškov facies) occur only in a small area in the central part of the Prague Basin. The Kralodvor corresponds approximately to the lower and middle Ashgill of the British scale; unfortunately, the lower boundary of the Ashgill (i.e. the base of the Pushgillian) cannot be correlated precisely with the lower limit of the Kralodvor, because the presence of the British Pushgillian, which is assumed as the earliest stage of the Ashgill, cannot be proved in Bohemia in spite of a continuous clayey sedimentation between the upper Beroun and lower Kralodvor. A significant restraint to apply the Ashgill Series in Bohemia is the fact that the base of the British Ashgill does not coincide with the base of any graptolite zone, but it is drawn within the *Pleurograptus linearis* Zone. According to Williams et al. (1972), the latter zone ranges from the upper Onnian (i.e. the uppermost Caradoc) through the Pushgillian to reach the lower Ashgill. In the Prague Basin, *Pleurograptus linearis* has not been found yet; in Bohemia, the Beroun/Kralodvor boundary is based on changes in the shelly fauna, trilobites, pelagic biotas (graptolites, acritarchs), as well as on a sudden appearance of a better oxygenated environment. This boundary may be applied without difficulties also in several basins of West Europe and North Africa.

The widespread *Aegiomena-Drabovia* fauna disappeared in the uppermost Beroun; in the Kralodvor, it was replaced by poorly diversified infaunal and epibenthic associations of inarticulate and small thin-shelled articulate brachiopods; most of the fauna was assigned to the deep-water *Rafanoglossa* Community whereas the *Foliomena* and *Proboscisambon* faunas are confined only to two interlayers of silty shales and lenticular clayey carbonates, respectively (survey of sessile benthos and communities: Havlfček and Vaněk 1966, 1990; Havlfček 1982; Štorch & Mergl 1989). Rather

19. Brachiopod assemblages in the Kralodvor (about in the lower-middle Ashgill). Graphs showing decreasing number of genera from the warm-temperature zone toward the circumpolar sphere, and the coefficients of association between 6 regions investigated (explanation: see text-fig. 4); Br - region of Sambre and Meuse Rivers, south of the Brabant Massif.



frequent epiplanktic brachiopods and miomerid trilobites have been assigned to the *Chonetidea radiatula* Community (Havříček & Vaněk 1990).

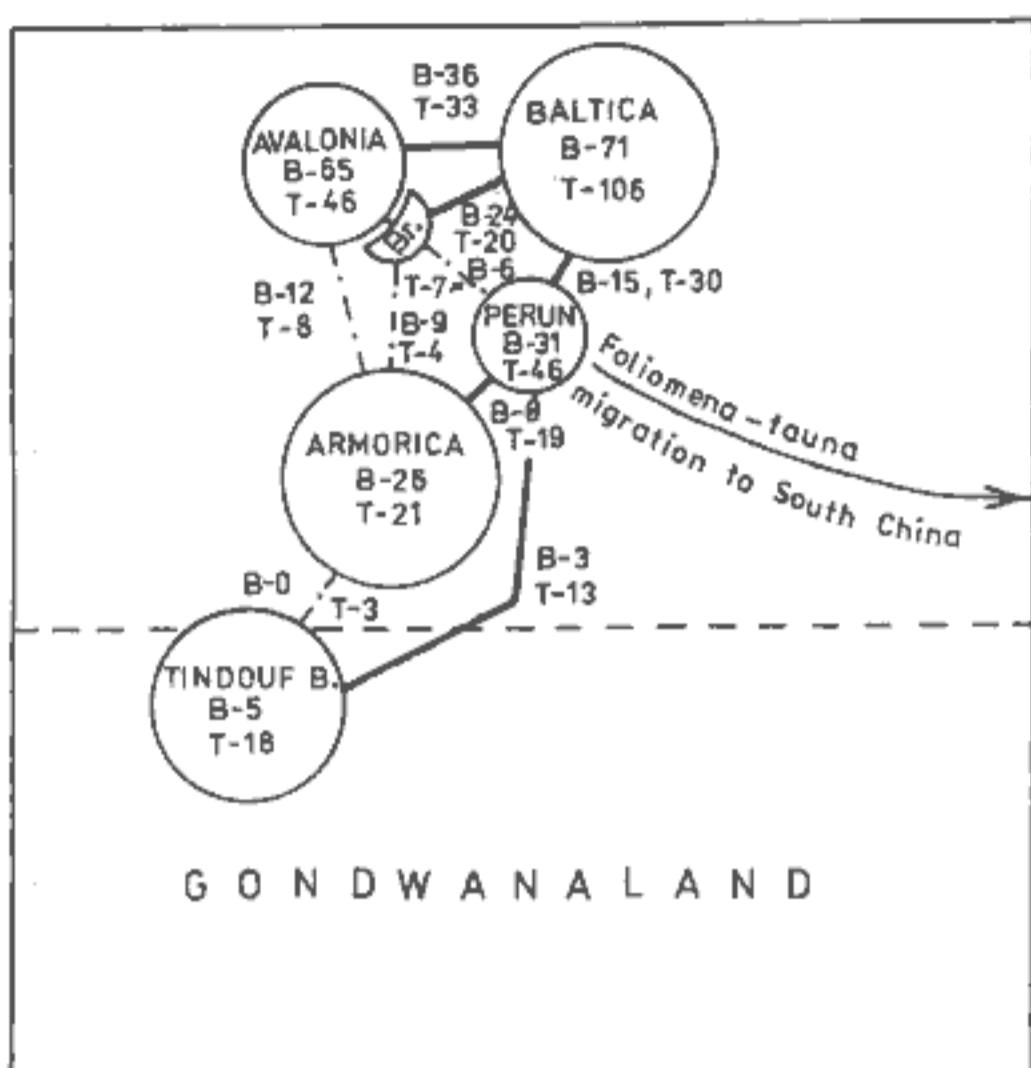
The Bohemian trilobite associations differ from those of the preceding Beroun Series; in addition to the indigenous Bohemian-type stocks, many immigrants appear in the Prague Basin. Of trilobites, which cross the Beroun/Kralodvor boundary, the most significant are *Actinopeltis*, *Cyclopyge*, *Eudolatites*, *Flexicalymene*, *Kloucekia*, *Onnia*, *Selenopeltis* and *Stenopareia*. Interesting are the "intermittent taxa" (Přibyl & Vaněk 1976) which were confined to the deeper and pelagic environments of the Šárka (*Sympysops*), Dobrotivá (*Degamella*, *Dindymene*, *Nankinolithus*), Libeň (lower Beroun: *Girvanopyge*), and Vinice Shales (lower part of the middle Beroun: *Dionide*) and re-appeared again in the deeper-water mudstones of the Kralodvor.

An important group are the Baltic and Avalonian-type trilobites, which colonized the Prague Basin during the Kralodvor; many of them are indigenous Baltic stocks inhabiting the Baltic regions and Scandinavia since the Middle Ordovician; some invaded the Prague Basin in the upper Beroun (*Raphiophorus*, *Lonchodus*) but most of them inhabited Bohemia during the Kralodvor (e.g. *Bronteopsis*, *Phillipsinella*, *Pseudosphaerexochus*, *Staurocephalus*, *Stubblefieldia*, *Telephina*, *Trochurus*).

The Kralodvor was subdivided by Havříček and Vaněk (1966) into the following trilobite horizons: 1. *Nankinolithus granulatus* (about the lower half of the sequence); 2. *Tretaspis seticornis seticornis* (most of the upper half of the sequence); 3. *Cryptolithus kosoviensis* (confined to the clayey carbonate horizon in the upper Kralodvor); 4. topmost Kralodvor is distinguished by a poorly diversified benthic association with numerous specimens of *Mucronaspis grandis* (=*Mucronaspis* Community; Štorch & Mergl 1989).

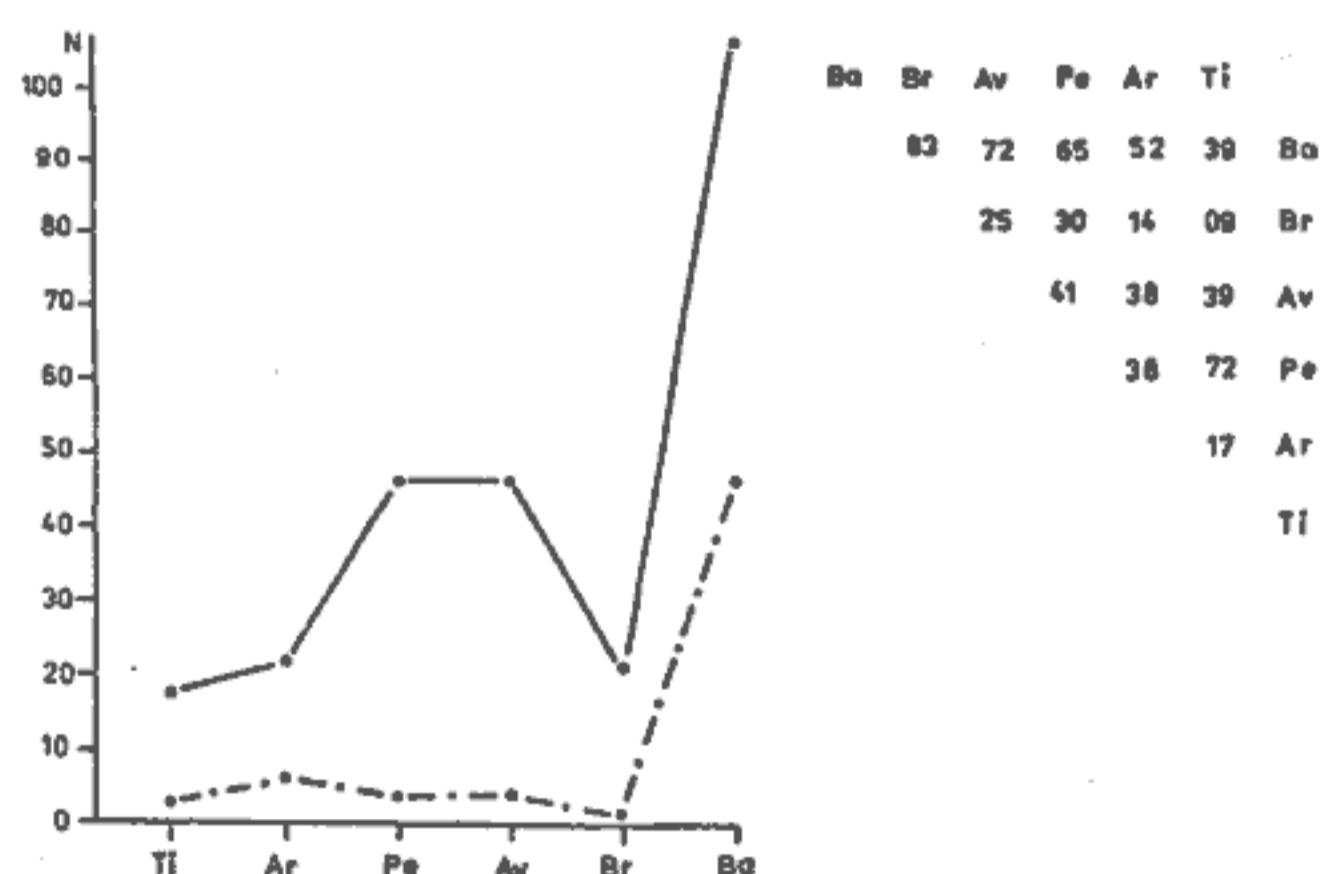
In western Europe, the echinoderms are prolific in a shallow, warm-water environment of the cystoid

limestones (e.g. *Glyptosphaerites*, *Maghabocystis*, *Caryocrinites*, *Heliocrinites*, *Caryocystites*, *Echinospaerites*, and many columnal plates of crinoids; Chauvel et al. 1975), whereas they are a subordinate component of the benthic associations in the Prague Basin;



21. Relation of separate plates and microplates in the Kralodvor (about in the lower-middle Ashgill); based on the brachiopod (B) and trilobite (T) assemblages (explanation: see text-fig. 6); Br - region of Sambre and Meuse Rivers, south of the Brabant Massif.

the clayey carbonate (upper Kralodvor) has so far yielded *Echinospaerites*, *Cheirocrinus*, *Mespilocystites tragermanicus* and crinoidal debris in a much deeper environment of the *Proboscisambon* Community (Štorch & Mergl 1989).



20. Trilobite assemblages in the Kralodvor (about in the lower-middle Ashgill). Graphs showing decreasing number of genera from the warm-temperature zone toward the circumpolar sphere, and the coefficients of association between 6 regions investigated (explanation: see text-fig. 4); Br - region of Sambre and Meuse Rivers, south of the Brabant Massif.

Graptolites are not frequent in the Kralodvor; *Glyptograptus teres* occurs in the lower part of the series, whereas the upper part, assigned by Štorch (1989) to the *Scalarigraptus angustus* Zone, contains besides the index species also *Dicellograptus laticeps*, *D. cf. morrisi*, and *Plegmatograptus? chuchlensis*. The uppermost layer of the Králův Dvůr Formation, overlying the clayey carbonate bed, has yielded *Glyptograptus cf. ojsuensis*. According to Štorch (1989), both the *S. angustus* and *G. cf. ojsuensis* Zones correspond to the upper part of the British *Dicellograptus anceps* Zone.

Microphytoplankton is abundant in the Kralodvor; all data concerning the acritarchs were summarized by Vavrdová (1989); according to her, the most typical species are *Orthosphaeridium insculptum* and *Beromia clipeata*. Further, the upper part of the Králův Dvůr Formation has yielded chitinozoans of the genera *Cyathochitina*, *Conochitina*, *Jenkinochitina* and *Rhabdochitina* in association of the spores *Nodospora cf. burnhamensis* and *Tetrahedraletes* sp. (recently discovered by O. Fatka).

In Armorica, the Kralodvor (i.e. the lower-middle Ashgill), if present, is developed as a thin sequence of limestones such as the Les Veaux micritic Limestone in Normandy; Rosan Limestone in western Brittany; Guiana Limestone in N.W. Spain (massive limestones and dolomites with debris of echinoderms); Cystoid Limestone in Celtiberia (with many echinoderms, brachiopods, conodonts, trilobites); Urbana Limestone in Central Spain (with bryozoans, echinoderms, brachiopods, tetracorals, lower Ashgill conodonts); and cystoid micritic limestones in the Carnic Alps, Austria. Due to a pronounced shallow-water environment, the benthic associations of Armorica are different from those of the deeper-water sediments of Bohemia. For this reason, it is difficult to fix precisely the lower limit of the Kralodvor in some areas of Armorica. In the Iberian Chains, the Biozone 6 (uppermost Fombuena Formation and Cystoid Limestone Formation; Villas 1985) corresponds in age to the Kralodvor Series and bears a characteristic suite of articulate brachiopods and trilobites (list of fossils: Villas 1985).

On the other hand, the precise determination of the Beroun/Kralodvor boundary beyond the Iberian Chains is impeded by the fact that several brachiopods of the Biozone 6 appeared as early as in the upper Beroun in the Montagne Noire, Sardinia, and Carnic Alps (e.g. *Leangella anaclyta*, *Iberomena sardoa*, *Nicolella actoniae*, *Eoanastrophia pentamera*) in association with significant Berounian elements such as *Drabovia*, *Svobodaina*, *Aegiomena*, *Dalmanitina*, *Nobiliasaphus*, and *Onnia*. In Sardinia, the regressive Domusnovas Formation is of Kralodvor age; its lower Maciurra Member contains a shallow-water brachiopod assemblage with several upper Berounian elements, and the upper Punta S'Argiola Member has yielded the brachiopods of

the deeper-water *Foliomena* fauna in association with numerous bryozoans, cystoids, trilobites, and conodonts (Leone et al. 1991); it is still questionable if the bases of the Králův Dvůr and Domusnovas Formations are coeval.

In the Tindouf Basin (Gondwana), the Upper Ktaou Formation is comparable to the Kralodvor Series of Bohemia; it consists of greenish and black claystones passing upward into the greywackes with numerous clayey-carbonate nodules and having yielded many Bohemian-type brachiopods and trilobites (e.g. *Chonetoides radiatula*, *Comatopoma*, *Actinopeltis*, *Brongniartella*, *Dionide*, *Eudolatites*, *Flexicalymene*, *Kloucekia*, *Mucronaspis*, *Onnia*, *Selenopeltis*) but no warmer-water elements of the Avalonian type, thus differing from the sequence in Armorica.

As follows from the analysis of lithology and biotas, the climate and position of microplates differed from those of the preceding Llanvirn, Dobrotivá and Beroun Series. Increase of temperature in the Kralodvor was a stimulus for the Baltic and Avalonian-type brachiopods and trilobites to colonize some areas of the Mediterranean Province. Due to a warmer climate, the earliest reefs and bioherms originated in central Spain (Urbana Limestone with many bryozoans, crinoids, and tetracorals; Fuganti & Serpagli 1968; Tamain 1971). The warmer-water fauna of the Anglo-Baltic type reached South Europe (Spain) but owing to a temperature gradient, it never invaded the Gondwanan epicratonic basins in the circumpolar sphere.

Another feature of the Kralodvor is the fact that all barriers that had prohibited faunal interchange between Perunica, Avalonia, and Baltica during the Dobrotivá and Beroun, faded away since the end of the Beroun. Thus, the shelly fauna and trilobites could loosely migrate between the Prague Basin, Holy cross Mts. (Poland), and Scandinavia (Sheehan 1973). According to Cocks and Rong Jia-yu (1988), the *Foliomena* fauna occupied the deeper, soft-bottom environment in many regions of the World such as the Prague Basin in Perunica, South China Plate, Avalonia, Baltica, and southern margin of Laurentia.

An easy interchange of benthic fauna between Perunica and Baltica indicates a gradual reduction of the Tornquist's Sea accompanied by growing proximity of Perunica and the Baltic continent. Judging from analysis of the fauna, the relation of Perunica to Armorica was somewhat looser than in the Beroun; some trilobite genera do occur in both the regions, but the distinctive development of Armorica is apparent from a prevalence of shallow-water cystoid limestones and presence of several gaps in sedimentation during the Kralodvor.

In the Upper Ordovician, nor the Rheic Sea presented a serious barrier against faunal migration between Avalonia and Armorica. Thus, the rise of temperature was succeeded by an influx of several Avalonian stocks into Armorica to inhabit the Iberian peninsula (the Iberian Chains; Villas 1985; Havlíček 1989). On the other hand,

the Rheic Sea functioned as a barrier between Belgium (region of Sambre and Meuse Rivers, south of the Caledonian Brabant Massif) and Armorica. This is evident from the fact that the Fosse Formation (about Kralodvor in age) has yielded a suite of 36 brachiopod genera mostly of the Baltic origin (24 of them were recorded in the Baltic regions; Sheehan 1988) but only 8 of them are in common to the Iberian Chains and Belgium (including the pandemic genera *Leptaena* and *Triplesia*). The same close Baltic affinity was found in Belgium among the trilobites (Lespérance & Sheehan 1988)

Data used for palaeogeographic reconstruction of the Kralodvor Perunica (Prague Basin). Brachiopoda - Acanthambonia, Actinomena, Aegiromena, Aegironetes, Anisopleurella, Anoptambonites, Anx, Boticum, Chonetoides, Cliftonia, Comatopoma, Conotreta, Cryptothyrella (=Hindella?), Cyclospira, Dedzetina, Eoanastrophia, Epitomyonia, Fardenia, Foliomena, Hirnantia, Jezercia, Karlicium, Kozlowskites, Leptaena, Leptesiina, Orbiculoidea, Proboscisambon, Rafanoglossa, Rafinesquina, Ravoletina, Salopina; further, Onnizetina has been found in the lowermost layer of the Králův Dvůr Formation (oolitic ferrolite) (Havlíček 1977; Havlíček & Mergl 1982).

Trilobita - Actinopeltis, Alceste, Amphitryon, Areia, Arthrorhachis, Birmanites, Brongniartella, Bronteopsis, Carmon, Cryptolithus, Cyclopyge, Decoroproetus, Degamella, Dindymene, Dionide, Duftonia, Eudolatites, Flexicalymene, Girvanopyge, Gravicalymene, Kloucekia, Leonaspis, Lonchodus, Meadowtownella, Microparia, Mucronaspis, Nankinolithus, Octillaenus, Onnia, Phillipsinella, Pseudosphaerexochus, Raphiophorus, Selenopeltis, Staurocephalus, Stenopareia, Stubblefieldia, Symphysops, Telephina, Tretaspis, Trochurus, Xenocybe (=Zetaproetus), Zazvorkaspis, Zdicella, Zetillaenus (Pek & Vaněk 1989).

Baltica (Vormsi and Pirgu Horizons, Baltic region). Brachiopoda - Acanthambonia, Anoptambonites, Apatorthis, Barbarorthis, Bekkeromena, Boreadorthis, Dalmanella, Dicoelosia, Elsaella, Eoplectodonta, Epitomyonia, Fardenia, Glyptorthis, Hebertella, Holtedahlina, Isorthis, Laticrura, Leptaena, Luhaiia, Mendacella, Mjoesina, Nicella, Onniella, Paucicrura, Pionodema, Plaeiomys, Platystrophia, Porambonites, Ptychopleurella, Rafinesquina, Resserella, Sampo, Strophomena, Thaerodonta, Triplesia, Vellamo, Wysogorskiella (Öpik 1930, 1933; Alichova 1953; Röömusoks 1959, 1963, 1964, 1981; Rubel 1971; Popov & Nolvak 1987). Further genera in Norway (mostly Tretaspis and Onniella associations): Chonetoides, Christiania, Cliftonia, Coolinia, Diambonia, Dolerorthis, Drabovia, Eoconetes, Eodinobolus, Eospirigerina, Eostropheodonta, Furcitella, Gunnarella, Hesperorthis, Hindella, Hirnantia, Katastrophomena, Leangella, Orbiculoidea, Orthambonites, Oxoplia, Rostricellula, Skenidioidea, Stegerhynchus, Streptis (Wright 1965; Brenchley & Cocks 1982).

Further genera in Poland and Sweden (mostly Foliomena fauna and minute inarticulate brachiopods): Cyclospira, Dedzetina, Foliomena, Kozlowskites, Leptesiina, Sericoidea (Sheehan 1973; Cocks & Rong Jia-yu 1988); Acrotretella, Hisingerella, Schizotreta (Holmer 1986).

Trilobita (Baltic regions, Sweden, Poland) - Acidaspis, Actinopeltis, Alceste, Amphilichas, Amphitryon, Ampyx, Apianurus, Areia, Arthrorhachis, Ascetopeltis, Astropoetus, Atractopyge, Birmanites, Brachyaspis, Brongniartella, Calyptaulax, Carmon, Ceratocephala, Ceraurinium, Cryptolithus, Cyamops, Cybeloides (Paracybeloides), Cyclopyge, Cyphoproetus, Deacybele, Decoroproetus, Degamella, Deiphon, Diacanthaspis, Dicranognus, Dicranopeltis, Dindymene, Dionide, Eobronteus, Eodindymene, Erratocrinurus (Celtocrinurus), E. (Erratocrinurus), Geragnostus, Hadromeros, Hammatoconemis (=Ovalocephalus), Harpidella, Hemiargus, Holotrachelus, Illaenus (Parillaenus), Isbergia, Isocolus, Isotelus (Isotella), Ityophorus, Leonaspis, Lichas, Liocnemis, Lonchodus, Mesotaphraspis,

Microparia, Miraspis, Mucronaspis, Nankinolithus, Novaspis, Oedicybele, Otarion (Beggaspis), Panarchaeogonus, Pandaspinapya, Panderia, Paraharpes, Parvigena, Phillipsinella, Placoparia (Hawleia), Platycoryphe, Platylidas, Pompeckia, Primaspis, Prionocheilus, Proceratocephala, Proetus, Pseudosphaerexochus, Raphiophorus, Remopleurella, Remopleurides, Scopolochasmops, Scotoharpes, Scharyia, Shumardia, Skelipyx, Solariproetus, Sphaeragnostus, Sphaerexochus (Korolevium), Sphaerocoryphe, Staurocephalus, Stenoblepharus, Stenopareia, Stubblefieldia, Stygina, Symphysops, Telephina, Thorslundops, Toernquistia, Toxochasmops, Tretaspis, Triarthrus, Trochurus, Warburgaspis, Wegelinia, Whittingtonia, Xenocybe, Zdicella, Zeliskella (Warburg 1925; Kielan 1960; Bruton & Owen 1979).

Armorica (Iberian Chains, L'Aulne, Finistère). Brachiopoda - Aberia (=Boticium?), Aegironetes, Dalmanella, Dolerorthis, Eoanastrophia, Epitomyonia, Eridorthis, Hedstroemina, Iberomena, Kozlowskites, Leangella, Leptaena, Leptesiina, McEwanella, Nicella, Orbiculoidea, Oxoplia, Palaeostrophomena, Porambonites, Ptychopleurella, Rostricellula, Saukrodictya, Schizophorella, Skenidioidea, Triplesia (Mélou 1971, 1990; Villas 1985). Further genus: Hesperinia (Asturias: Villas, Gisbert & Montesinos 1989). Recently discovered in Sardinia: Christiania, Cyclospira, Foliomena, Jezercia, Onniella (Leone et al. 1991).

Trilobita - Alceste, Bronteopsis, Calymenella, Cekovia, Cyclopyge, Dalmanitina, Dicranopeltis, Hammatoconemis, Heliomera (Heliomeroides), Illaenus (Parillaenus), Mucronaspis, Phillipsinella, Primaspis, Pseudosphaerexochus, Radiaspis, Raymondaspis, Stenopareia, Symphysops, Tiresias, Ulugtella, Whittingtonia (Henry 1980; Rábano 1984). Recently discovered in Sardinia: Birmanites, Madygenia, Nankinolithus, Ovalocephalus, Schumardoella, Telephina (Leone et al. 1991). After submitting this paper for print, the following trilobites have been discovered in the Cystoid Limestone (Iberian Chains; Hamman 1992): Actinopeltis, Diacanthaspis, Dreyfussina, Hispaniaspis, Holdenia, Lamproscutellum, Lichas, Nobiliashpus, Panarchaeogonus, Prionocheilus, Radnoria, Rorringtonia, Selenopeltis, Snajdria, Thaleops, Zetillaenus.

Gondwana (Tindouf Basin). Brachiopoda - Aphanomena, Chonetoides, Comatopoma, Eoconetes, Hirnantia (Havlíček 1971).

Trilobita - Actinopeltis, Amphitryon, Baniaspis, Brongniartella, Calymenella, Cryptolithus, Dionide, Dreyfussina, Eudolatites (Deloites), E. (Eudolatites), Flexicalymene, Kloucekia, Lichas, Mucronaspis, Octillaenus, Onnia, Selenopeltis, Stenopareia (Destombes 1966, 1967, 1972).

Avalonia (Wales). Brachiopoda - Anisopleurella, Catazyga, Chonetoides, Christiania, Craniops, Cremonthis, Cyclospira, Dalmanella, Diambonia, Dicoelosia, Dolerorthis, Eodinobolus, Epitomyonia, Eremotrema, Fardenia, Glyptorthis, Gunnarella, Hesperorthis, Katastrophomena, Kjaerina, Kullervo, Mjoesina, Nicella, Orbiculoidea, Orthambonites, Oxoplia, Philhedra, Plaeiomys, Platystrophia, Plectatrypa, Porambonites, Portranella, Protozyga, Ptychopleurella, Ravoletina, Rhynchotrema, Sampo, Saukrodictya, Schizonema, Schizophorella, Skenidioidea, Sowerbyella, Spinorthis, Strophomena, Triplesia, Vellamo (Hiller 1980; Brenchley & Cullen 1984). Further genera in the Portrane Limestone (Ireland): Acanthocrania, Eoconulus, Leptobolus, McEwanella, Multispinula, Paterula, Philhedrella, Rowellella, Scaphorthis, Schizotreta, Spondylotreta, Streptis, Trematis (Wright 1963, 1964). Further genera in the Foliomena fauna: Dedzetina, Eopholidostrophia, Eoplectodonta, Eostropheodonta, Folionema, Leptesiina (Cocks & Rong Jia-yu 1988). Trilobita (England, Wales) - Acidaspis, Amphitryon, Arthrorhachis, Ascetopeltis, Atractopyge, Birmanites, Brongniartella, Calyptaulax, Ceraurinium, Cybeloides (Paracybeloides), Decoroproetus, Diacanthaspis, Dindymene, Duftonia, Encrinuroidea, Encrinurus, Erratocrinurus, Flexicalymene, Gravicalymene, Harpidella, Illaenus (Parillaenus), Kloucekia, Lehua, Leonaspis, Lichas, Liocnemis, Lonchodus, Mucronaspis, Oedicybele, Onnicalymene, Paraharpes, Paraproetus, Phillipsinella, Platylidas, Primaspis, Prionocheilus,

Pseudosphaerexochus, *Raphiophorus*, *Sphaerocoryphe*, *Staurocephalus*, *Stenopareia*, *Stygina*, *Toxochasmops*, *Tretaspis*, *Ulugtella*, *Whittingtonia* (Thomas et al. 1984).

Belgium (south of the Caledonian Brabant Massif). Brachiopoda - *Anisopleurella*, *Boreadorthis*, *Catazyga?*, *Chonetidea*, *Christiania*, *Costistrophomena*, *Cyclospira*, *Dalmanella*, *Diambonia*, *Dicoelosia*, *Eospirigerina*, *Fardenia*, *Foliomena*, *Glyptorthis*, *Katastrophomena*, *Kiaeromena*, *Kullervo*, *Laticrura*, *Leangella*, *Leptaena*, *Luhai*, *Nicolella*, *Oxoplecta*, *Platystrophia*, *Portranella*, *Ptychoglyptus*, *Ptychopleurella*, *Reuschella*, *Sampo*, *Saukrodictya*, *Skenidiooides*, *Sowerbyella* (*Rugosowerbyella*), *Spinorthis*, *Strophomena*, *Triplesia*, *Vellamo* (Sheehan 1988).

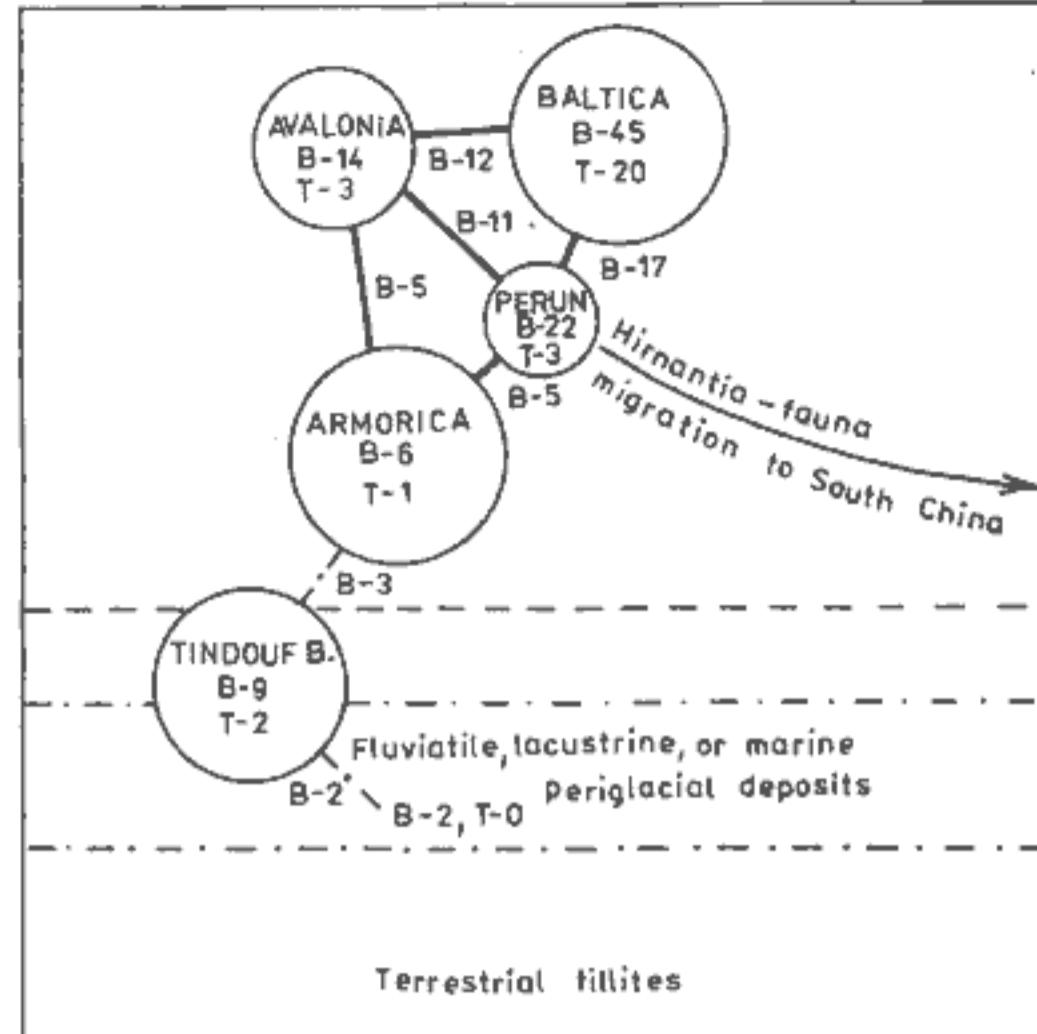
Trilobita - *Amphilichas*, *Arthrorhachis*, *Atractopyge*, *Calyptaulax*, *Cybeloides*, *Diacylomene*, *Dindymene*, *Enocrinurus*, *Illaenus*, *Lichas*, *Novaspis*, *Otarion*, *Panderia*, *Phillipsinella*, *Platylichas*, *Primaspis*, *Prionocheilus*, *Remopleurides*, *Sambremesusaspis*, *Sphaerexochus*, *Sphaerocoryphe*, *Stenopareia*, *Toxochasmops*, *Tretaspis* (Lespérance & Sheehan 1988).

Kosov

The Kosov is the most dramatic epoch of all the Ordovician series. The topmost Ordovician is distinguished by drastic cooling of climate, appearance of an extensive continental glaciation over most of Gondwana, eustatic lowering of sea level, intensification of faulting, destruction of pre-Kosovian community structures, and appearance of a widespread, shallow-water Hirnantia fauna. All these features, including an easy global correlation, speak in favour of proposing the Kosov as a separate series in spite of its not too long duration (Havliček & Marek 1973). On the other hand, the Hirnantian, which equals in age to the Kosov, is considered as the latest stage of the Ashgill Series in the British scale.

The fundamental features of the latest Ordovician (e.g. glaciation, changeover in benthic faunas) were dealt with in detail in many papers; recently, they were summarized by Rong Jia-yu (1984), Rong jia-yu & Harper (1988), Sheehan (1988), Havliček (1989) and many others. For this reason, we refer in the following text only to those events that can help for a better understanding of processes in the Mediterranean Province.

The beginning of the Kosov coincides with a sudden cooling of climate that resulted in a continental glaciation accompanied by a sudden drop of sea level (by about 50-100 m) and, consequently, in a disruption of the pre-Kosov brachiopod habitats (Sheehan 1975, 1988). The eustatic lowering of the sea level drained most the seaways and produced narrow belts of shallow water around the emergent continents (Sheehan 1975). In the Mediterranean Province, however, the behaviour of several areas was different; due to faulting, some areas underwent a further transgression of glacio-marine sediments over the Beroun-age or even older rocks (e.g. in the Tindouf Basin, Gondwana; Destombes 1968, 1971). Thus, the extremely shallow-water shelves originated that were colonized by poorly diversified cold-water faunas.



22. Relation of separate plates and microplates in the Kosov (about in the upper Ashgill); based on the brachiopod (B) and trilobite (T) assemblages (explanation: see text-fig. 6).

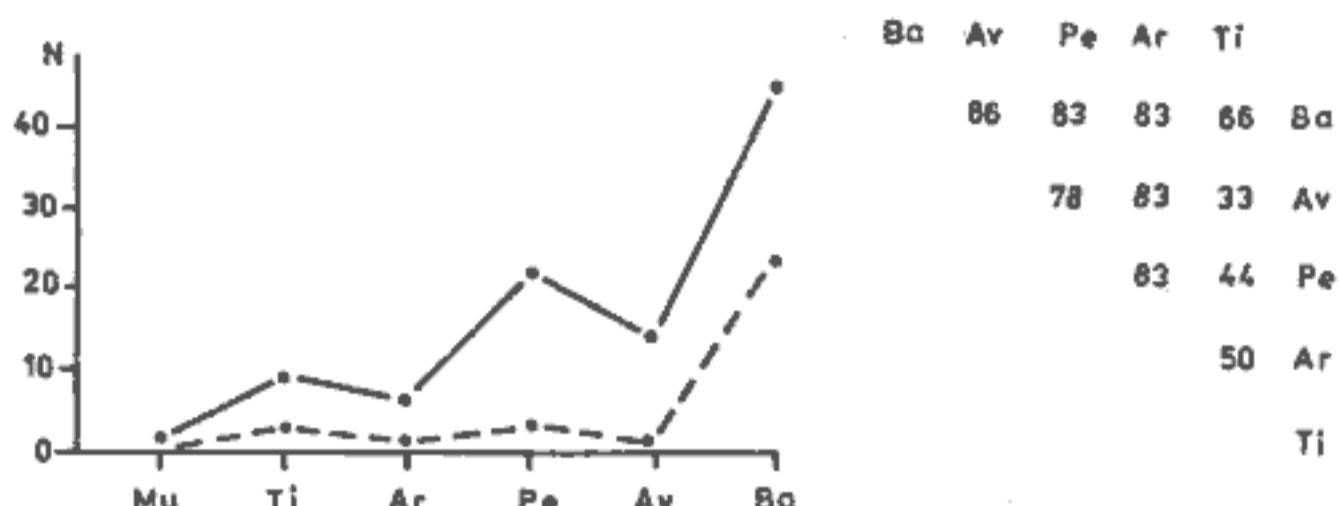
According to Deynoux and Trompette (1981), the erosional unconformity between the glacio-marine sediments and pre-Kosov rocks passes laterally into a marked angular unconformity towards the Mauritanides.

The faulting had to exist also in Armorica; according to our opinion, the simplest way how to explain the erosional unconformity between the pre-Kosov formations and the clast-bearing glacio-marine sediments (diamictites) is to presume a considerable shallowing or even a regression of the sea in the Kralodvor that was immediately succeeded by a further deepening of the basin after a reactivation of older fault zones. This is apparent from the fact that the Kralodvor sediments were either formed as shallow-water cystoid limestones or they were absent altogether (destroyed in a pre-Kosov regressive event?) in many areas of the Armorican Massif and Iberian peninsula (Robardet & Doré 1988). From the global point of view, this process is unusual as the uppermost Ordovician is an epoch of a marked glacio-eustatic regression event recognized in many regions of the World.

To sum up, the early Kosov faulting was established in Gondwana as a result of reactivating the old Pan-African faults (Biju-Duval et al. 1981), further in Armorica (see above), and in the Oslo-Asker district of Baltica where Brenchley and Cocks (1982) discovered the early Hirnantian fault movements.

In Perunica, the Kosov reflects both the glacio-eustatic and tectono-eustatic movements. The tectonic deformation is presumed in the Prague Basin where the marginal segments turned into periodically rising zones that became source areas of the clastic material consisting

23. Brachiopod assemblages in the Kosov (about in the upper Ashgill). Graphs showing decreasing number of genera from the warm-temperature zone toward the circumpolar sphere, and the coefficients of association between five regions investigated (explanation: see text-fig. 4); Mu - Gondwana, Murzúq Basin.



of grains, pebbles, and angular fragments of rocks of Ordovician and Proterozoic ages. Due to existence of rising zones, a high-land glaciation could develop in an area far way off the circumpolar sphere. The diamictites (two beds in the lowest Kosov) may best be explained as reworked material coming from the early Kosovian moraines and floating ice (e.g. dropstones); Štorch and Mergl (1989) supposed that the slumping and gravity flows played an important role in their sedimentation. According to Brenchley and Štorch (1989), the Kosovian diamictites are probable deposits of seasonal ice.

The Rožmitál Graben differs from the Prague Basin in that it contains a fan of diamictite ranging in thickness from a few metres near Hútě to several tens of metres that occupy most of the Kosov sequence near Bezděkov (Havlíček 1977).

In the Saxothuringian Zone, the monotonous, almost black, buff-weathering and non-bedded silty shale sequence was assigned to the uppermost Ordovician (e.g. Jaeger 1988). Sandy rock-detritus and isolated sandstone boulders (drop-stones?) indicate a probable glacio-marine origin. Owing to presence of the Bohemian-type fossils, origin of these boulders should be sought in Perunica.

In the Lugian Zone (Krkonoše Mts.), the lower part of the Poniklá Group is comparable in age and lithology to the Kosov Formation and overlies unconformably the Lower Ordovician or even earlier sequences (Chaloupský in Suk et al. 1984).

It is little to add to fauna of the uppermost Ordovician; complete lists of fossils were published by Rong Jia-yu and Harper (1988) and Cocks (1988). Brachiopod synecology (ecological crisis) was discussed by Sheehan (1975). According to Rong Jia-yu (1984), the *Hirnantia* fauna extended from the circumpolar sphere to the temperature and subtropical latitudes. It is worth to note that a temperature gradient affected the brachiopod distribution also in the Mediterranean Province; the belt with *Plectothyrella libyca* (=Bani Province of Rong Jia-yu & Harper 1988) was confined to the circumpolar, pronouncedly cold-water zone bearing sequences of subglacial to periglacial deposits intercalated with marine sandstones that have yielded *Plectothyrella libyca* and *P. chauveli* (Tindouf and Murzúq Basins) accompanied by *Hirnantia sagittifera* and species of *Arenorthis* and *Destombesium* (Havlíček 1990). The second belt with

Plectothyrella crassicostis (=Kosov Province of Rong Jia-yu and Harper 1988) occurred beyond the circumpolar sphere and extended from Perunica eastwards to Central China; the *Hirnantia* fauna of this belt is rather richly diversified (list of fossils: Havlíček 1982, 1989; Rong Jia-yu 1984). It was called "typical *Hirnantia* fauna" and assigned to the temperature or even subtropical zone (Rong Jia-yu & Harper 1988). In spite of low-latitude position of Perunica, its cold-water character is evident from the presence of diamictite layers and typical dropstones in the Kosov Formation. The temperature gradient between the zones of *Plectothyrella libyca* and *P. crassicostis* was no important barrier against faunal migration as it is shown by presence of *Hirnantia sagittifera* and species of *Aphanomena* and *Eostropheodonta* in both the climatic zones.

In the Mediterranean Province, it is difficult to establish the graptolite zones because *Diplograptus bohemicus* was found only in the upper part of the Kosov Formation. A fairly complete graptolite succession is in Central China where the uppermost Ordovician contains the zones of *Diceratograptus mirus* (W₄), *Paraorthograptus uniformis* (W₅), and *Diplograptus bohemicus* (W₆); the correlation of the *Diceratograptus mirus* Zone with the lower Kosov, of course, needs further verification.

Microfossils are not yet known adequately in the Kosov; the most abundant association in the Prague Basin (over 100 species) was discovered by Vavrdová (1989) at Hlásná Třebaň; according to her, the surprising diversity should be explained as a mixture of taxa of Precambrian, Cambrian and Lower Ordovician ages, all redeposited in the upper Kosov in association with several Upper Ordovician elements. For this reason, these microfossils are little reliable for biostratigraphical purposes. Among the Upper Ordovician elements collected at Hlásná Třebaň, *Aremorianum syringosagis*, *Beromia clipeasta*, *Diexallophasis denticulata*, *Orthosphaeridium inflatum*, and a triapsid *Veryhachium* occur both in the upper Kosov at Hlásná Třebaň as well as in the lowermost layers of the Kosov at Levín.

Geographical arrangement of plates and microplates in the topmost Ordovician is quite different from that in the Middle Ordovician. All differences in composition and diversification of benthic faunas can be explained in terms of temperature gradients between the circumpolar,

temperature and even subtropical zones. The Tornquist's and Rheic Seas, owing to their gradual reduction and absence of significant longitudinal currents, presented no more barriers against faunal migration in the Kosov.

Conclusions

Each Ordovician series was treated as an epoch bearing distinctive fauna and microflora, and reflecting the main geological events. The general aspects concerning the Mediterranean Province are as follows:

1. In Perunica, the bases of the Arenig and Llanvirn coincide with significant transgressions that succeeded after short-lasting regression events; each transgression was accompanied by a sudden influx of new fauna. The lowest layers of the Klabava Formation, corresponding in age to the *Clonograptus* Zone, are characterized by an appearance of latest Tremadoc-earliest Arenig taxa of acritarchs and chitinozoans. The enormous, lowest Llanvirn invasion of new fauna mostly of Armorican and Avalonian origins, was preceded by a weak influx of West European elements in the uppermost Arenig (upper Klabava Formation).

2. In the Mediterranean Province, the Llanvirn, Dobrotivá and Beroun are distinguished by predominance of black-shale lithofacies alternating with sandstone beds (more frequent in the Beroun than in the Llanvirn).

3. By contrast to the Lower Ordovician series, the Dobrotivá and Beroun do not begin with a marked transgression synchronous over most of the Mediterranean Province; for this reason, the Llanvirn/Dobrotivá boundary is based on disappearance of didymograptids in the topmost Llanvirn and a subsequent appearance of "*Glyptograptus teretiusculus*".

4. Owing to lack of graptolites, a sudden expansion of the *Aegiromena-Drabovia* fauna was used for drawing the base of the Beroun.

5. The base of the Kralodvor coincides with a weak (in Perunica) or considerable (in Gondwana) transgression of the sea, whereas in the West European basins the shallow-water environment or even gaps in sedimentation occurred.

6. The Kosov (coeval with the Hirnantian Stage) is regarded as a separate series although its duration is probably shorter than in the other Ordovician series; it is distinguished by a sudden cooling of climate, continental glaciation, and significant reactivation of the earlier fault zones; due to the latter event, the Kosovian glacio-marine sediments overlie with a weak to pronounced unconformity the pre-Kosov rocks in several areas of the Mediterranean Province, whereas a considerable fall in sea level was established in many regions of the World. Further, the Kosov is characterized by a widespread *Hirnantia* fauna.

7. Perunica was established as a separate microcontinent occurring in proximity of Baltica during

the Cambrian and lowermost Ordovician (Tremadoc); due to spreading of the Tornquist's Sea, the distance between Perunica and Baltica reached its maximum during the Middle Ordovician as shown by almost absolute absence of benthic elements in common to both the regions.

8. The Dobrotivá, lower and middle Beroun were epochs of maximum provinciality in Perunica.

9. Judging from the brachiopod and trilobite associations, the spreading period was succeeded by gradual closing of the Tornquist's Sea since the upper Beroun as shown by an increasing influx of the Baltic elements into the Perunican basins. This process terminated in the uppermost Ordovician (Kosov) with total disappearance of barriers prohibiting faunal migrations between the Mediterranean Province (including Perunica), Baltica and Avalonia.

10. Changes in composition of shelly fauna and trilobites in Perunica, Armorica, Avalonia, Gondwana and Baltica are shown in text-figs. 4-23 compiled for each Ordovician series. These biogeographic data have been used for our considerations about temperature gradients, possible migration routes, and in an attempt to reconstruct the paleogeography of the Mediterranean zoogeographical Province (including the Rheic and Tornquist's Seas; see text-fig. 3).

11. The present paper should serve for a better understanding of the series division in the Bohemian Ordovician, and for a correlation of the Bohemian series with that of other regions of the Mediterranean Province. Thus, it should be considered as a contribution to the projects of the Subcommission on Ordovician Stratigraphy.

*K tisku doporučil I. Chlupáč
Přeložil V. Havlíček*

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Mikrokontinent Perunika v ordoviku (jeho postavení v rámci mediteránní provincie, revize oddělení, bentická a pelagická společenstva)

(Resumé anglického textu)

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Každé ordovické oddělení (série) je hodnoceno jak z hlediska bentických a pelagických společenstev, tak z hlediska klimatických a paleogeografických změn. V mediteránní provincii se báze tremadoku, arenigu a llanvirnu zpravidla kryje s mořskou transgresí, která následuje po krátké regresní epizodě. Oddělení llanvirnu, dobrotiv a beroun jsou charakterizována převahou černých břidlic (tj. anoxicke facie), které mohou obsahovat různě mocné sledy písčitých hornin. Na rozdíl od starších ordovických jednotek oddělení dobrotiv a beroun nepočítají v mediteránní provincii do zjištěné transgresí. Proto spodní hranice dobrotivu je stanovena hlavně na vývoji graptolitových faun (vymření didymograptidů na konci llanvirnu a následné objevení druhu "*Glyptograptus teretiusculus*"). Rovněž počátek berounu je stanoven na výrazné změně ve složení fauny; je dobré zjistitelný podle náhlého nástupu bohatě diverzifikované aegiromenové a draboviové fauny. Báze královorova odpovídá slabé až výrazné mořské transgresi (např. v pražské pánvi a v Maroku), kdežto v západní Evropě panuje v tomto období mělkovodní sedimentace, místy spojená s hiány. Kosov je považován za samostatné oddělení navzdory svému poměrně krátkému trvání; vyznačuje se globálním ochlazením klimatu, kontinentálním zaledněním Gondwany a oživením starých tektonických linií. V důsledku této tektonické aktivity spočívají kosovské glaciomarinní uloženiny se slabou až značnou diskordancí na předkosovských horninách (např. v četných místech v Armorice a Gondwaně), kdežto v jiných částech světa je kosov obdobím regrese v důsledku glacioeustatických pohybů. Dále se kosov vyznačuje nástupem hirnantiové fauny, známé jak ze severní Afriky, tak z Evropy a jižní Číny.

Mediteránní provincie zahrnuje různé typy sedimentačních pánví v prostoru mezi Gondwanou a severoevropským kontinentem (Baltikou). V této práci je stanovena Perunika jako samostatný mikrokontinent ležící v blízkosti Baltiku během kambria a tremadoku, což dosvědčuje množství společných prvků bentické a nektobentické fauny. Následkem rozširování Tornquistova moře se vzdálenost mezi Perunikou a Baltikou postupně zvětšovala, až dosáhla svého maximum ve středním ordoviku. Zvláště pozoruhodné oddělení je dobrotiv, v němž v důsledku značného plošného rozsahu Tornquistova moře a za spoluúčasti podélných mořských proudů chybějí jakékoli společné elementy v bentických společenstvech Peruniky a Baltiky.

Konec ordoviku (tj. kralodvor a kosov) se vyznačuje opětným uzavíráním Tornquistova moře, což dokumentuje snadné migrace faun mezi pánevemi Peruniky a Baltiky.

Z hlediska paleogeografického významu a postupného přesunování z vysokých jižních šírek směrem k rovníku Perunika srovnatelná s Armorikou. Podle paleomagnetických měření (Krs et al. 1986, 1987) se střední Čechy, které jsou součástí Peruniky, postupně přemisťovaly z 39° j.š. v raném středním kambriu přes 29° j.š. ve vrchním kambriu až na 28° j.š. ve spodním ordoviku; proces přemisťování Peruniky pokračoval i v následujících obdobích. Podle paleomagnetických měření je též pravděpodobná postupná rotace Peruniky.

Vysvětlivky k obrázkům

1. Pozice pražské páne v rámci Českého masívu (silně zjednodušeno).
1 - ordovik; 2 - variské plutonity; 3 - horniny předordovického (převážně předpaleozoického) stáří; 4 - možnost výskytu spodnopaleozoických prvků v pestré sérii moldanubické zóny; 5 - devon a karbon moravskoslezské pánve; 6 - možné výskyty staršího paleozoika v jednotkách moravika a silesika; 7 - variské amfibolity (severní Morava); 8 - krystalinický podklad brunovistulika; 9 - synsedimentární zlomy a flexury; 10 - hlavní zlomová pásma; 11 - přesmyky, příkrovky; 12 - hlavní zlomová pásma použitá variskými granitoidy pro jejich intruzi; Rožm. - ordovik v rožmitálské brázdě; Tý - ordovik u Týniště nad Orlicí (východní Čechy).
2. Porovnání hlavních vrstevních sledů ordoviku v rámci Peruniky.
1 - převážně černé břidlice; 2 - zelené břidlice a prachovce; 3 - červené sedimenty; 4 - prachovce; 5 - střídání pískovců a břidlic; 6 - pískovce, křemence; 7 - diamiktity, doklady pro zalednění (drop-stones); 8 - sedimentární silicity; 9 - sedimentární železné rudy; 10 - pyroklastika.
3. Rekonstrukce paleogeografických poměrů v mediteránní provincii ve svrchním ordoviku (přibližně v berounském oddělení); skotsko-apalačská zóna (Laurentia) vynechána.
1 - doklady pro zalednění; 2 - biogenní útesy; 3 - rozšíření rodu *Sowerbyella*; 4 - rozšíření rodu *Aegirorema*; 5 - předpaleozoické štity; 6 - oblasti s význačnou mořskou regresí v berounu; 7 - marinní a fluviomarinní uloženiny (převážně tigillitové společenstvo); 8 - oblasti s převahou lingulidních brachiopodů; 9 - marinní uloženiny s převahou aegiromeno-draboviové fauny; též společenstva anglo-waleského a baltického typu; AP - Avalonia; B - brabantský masív; BV - brunovistulikum; PE - Perunika.
4. Brachiopodová společenstva v tremadoku. Vlevo grafy ukazují klesající četnost rodů od teplovodních pánví k cirkumpolární oblasti. Plná čára: celkový počet rodů v každé ze sledovaných oblastí; přerušovaná čára: počet endemických rodů v každé ze sledovaných oblastí. Vpravo asociační koeficienty mezi 6 sledovanými oblastmi. N - počet rodů; Ar - Armorika; Av - západní Avalonia; Ba - Baltika; Ld - Gondwana ("lingulidní" doména); Pe - Perunika; Ti - Gondwana (tindoufská pánev).
5. Trilobitová společenstva v tremadoku. Grafy ukazují klesající četnost rodů od teplovodních pánví směrem k cirkumpolární oblasti a asociační koeficienty mezi 6 sledovanými oblastmi (vysvětlivky jako u obr. 4).
6. Vzájemný vztah desek a mikrodesek v tremadoku na základě rozboru brachiopodových (B) a trilobitových (T) společenstev. V kruzích celkový počet rodů, mezi kruhy počet společných rodů pro obě oblasti. Plné čáry: blízké vztahy; přerušované čáry: silně omezené vztahy.
7. Brachiopodová společenstva v arenigu. Grafy ukazují klesající četnost rodů od teplovodních pánví směrem k cirkumpolární oblasti a asociační koeficienty mezi 6 sledovanými oblastmi (vysvětlivky jako u obr. 4).
8. Trilobitová společenstva v arenigu. Grafy ukazují klesající četnost rodů od teplovodních pánví směrem k cirkumpolární oblasti a asociační koeficienty mezi 6 sledovanými oblastmi (vysvětlivky jako u obr. 4).
9. Vzájemný vztah desek a mikrodesek v arenigu na základě rozboru brachiopodových (B) a trilobitových (T) společenstev (vysvětlivky jako u obr. 6).
10. Brachiopodová společenstva v llanvirnu. Grafy ukazují klesající četnost rodů od teplovodních pánví směrem k cirkumpolární oblasti a asociační koeficienty mezi 6 sledovanými oblastmi (vysvětlivky jako u obr. 4).
11. Trilobitová společenstva v llanvirnu. Grafy ukazují klesající četnost rodů od teplovodních pánví směrem k cirkumpolární oblasti a asociační koeficienty mezi 6 sledovanými oblastmi (vysvětlivky jako u obr. 4).
12. Vzájemný vztah desek a mikrodesek v llanvirnu na základě rozboru brachiopodových (B) a trilobitových (T) společenstev (vysvětlivky jako u obr. 6).
13. Brachiopodová společenstva v dobrotivu (llandeilu). Grafy ukazují klesající četnost rodů od teplovodních pánví směrem k cirkumpolární oblasti a asociační koeficienty mezi 6 sledovanými oblastmi (vysvětlivky jako u obr. 4).
14. Trilobitová společenstva v dobrotivu (llandeilu). Grafy ukazují klesající četnost rodů od teplovodních pánví směrem k cirkumpolární oblasti a asociační koeficienty mezi 6 sledovanými oblastmi (vysvětlivky jako u obr. 4).
15. Vzájemný vztah desek a mikrodesek v dobrotivu (llandeilu) na základě rozboru brachiopodových (B) a trilobitových (T) společenstev (vysvětlivky jako u obr. 6).
16. Brachiopodová společenstva v berounu (přibližně v caradoku). Grafy ukazují klesající četnost rodů od teplovodních pánví směrem k cirkumpolární oblasti a asociační koeficienty mezi 6 sledovanými oblastmi (vysvětlivky jako u obr. 4).
17. Trilobitová společenstva v berounu (přibližně v caradoku). Grafy ukazují klesající četnost rodů od teplovodních pánví směrem k cirkumpolární oblasti a asociační koeficienty mezi 6 sledovanými oblastmi (vysvětlivky jako u obr. 4).
18. Vzájemný vztah desek a mikrodesek v berounu (přibližně v caradoku) na základě rozboru brachiopodových (B) a trilobitových (T) společenstev (vysvětlivky jako u obr. 6).
19. Brachiopodová společenstva v královoru (přibližně ve spodním a středním ashgili). Grafy ukazují klesající četnost rodů od teplovodních pánví směrem k cirkumpolární oblasti a asociační koeficienty mezi 6 sledovanými oblastmi (vysvětlivky jako u obr. 4).
20. Trilobitová společenstva v královoru (přibližně ve spodním a středním ashgili). Grafy ukazují klesající četnost rodů od teplovodních pánví směrem k cirkumpolární oblasti a asociační koeficienty mezi 6 sledovanými oblastmi (vysvětlivky jako u obr. 4); Br - oblast povodí Sambre a Meuse j. od brabantského masívu.
21. Vzájemný vztah desek a mikrodesek v královoru (přibližně ve spodním a středním ashgili) na základě rozboru brachiopodových (B) a trilobitových (T) společenstev (vysvětlivky jako u obr. 6); Br - oblast povodí Sambre a Meuse j. od brabantského masívu.
22. Vzájemný vztah desek a mikrodesek v kosovu (přibližně ve svrchním ashgili) na základě rozboru brachiopodových (B) a trilobitových (T) společenstev (vysvětlivky jako u obr. 6).
23. Brachiopodová společenstva v kosovu (přibližně ve svrchním ashgili). Grafy ukazují klesající četnost rodů od teplovodních pánví směrem k cirkumpolární oblasti a asociační koeficienty mezi 5 sledovanými oblastmi (vysvětlivky jako u obr. 4); Mu - Gondwana, murzúcká pánev.

Le Microcontinent Perunica dans l'Ordovicien (sa position dans la Province Méditerranéenne, les divisions en Séries, les associations benthiques et pélagiques)

Mots clés: Ordovicien, province Méditerranéenne, Massif Bohémien, Mer de Tornquist, associations benthiques, microphytoplancton

Perunica, englobant la majeure partie du Massif Bohémien, est considérée dans ce travail comme une microplaqué distincte entre les cratons gondwana et nord européen (balte); à de hautes latitudes sud au Cambrien Moyen, elle a progressivement dérivé en traversant le paléoéquateur jusqu'aux basses latitudes nord au Paléozoïque supérieur. Toutes les Séries ordoviennes présentent des unités naturelles et sont le reflet des principaux événements géologiques tels que les mouvements tectono-eustatiques et glacio-eustatiques. Dobrotivá (approximativement Llandeilo) et Berounka (approximativement Caradoc) sont des époques de provincialisme maximal tandis que Kralodvor et Kosov sont pauvres en genres endémiques de Brachiopodes et Trilobites. La Mer de Tornquist n'a joué un rôle de barrière que pendant l'Ordovicien moyen, alors qu'elle n'interdisait pas les migrations fauniques entre Perunica et Baltica au Tremadoc, Kralodvor et Kosov. Les changements affectant les associations fauniques reflètent, seulement les positions respectives des plaques et microplaques (c'est à dire Baltica, Gondwana, Ouest Avalonia, Armorica et Perunica), mais aussi les gradients climatiques; le domaine circumpolaire (Gondwana) a livré une faune benthique nettement moins diversifiée que les autres régions du monde.

Des listes de genres de Brachiopodes et Trilobites ont été établies pour servir de bases fiables à nos considérations paléogéographiques.

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