GEOLOGICA CARPATHICA, 51, 1, BRATISLAVA, FEBRUARY 2000
37–48

RECONSTRUCTION OF SYN- AND POSTSEDIMENTARY TECTONIC EVENTS IN FLYSCH BASIN FROM LIMESTONE PEBBLES VARIATION: DRAHANY CULM OF THE MORAVIAN RHENOHERCYNIAN ZONE

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(Manuscript received June 19, 1998; accepted in revised form December 8, 1999)

Abstract: The microfacies of limestone pebbles from the Culm conglomerates of the Drahany Upland were examined in this study. The established groups of microfacies with similar features have been interpreted in terms of sedimentary environment and the content of facies of various age was analysed. For the pebbles of Upper Famennian–base of Middle Viséan limestones, the ratio of those facies which are interpreted as calciturbidites, hemipelagites and pelagites to the microfacies of shallower environments rises significantly in all Culm formations. No such facies were found in the pebbles of the Givetian-Lower Famennian and Middle-Upper Viséan limestones. Comparison of the ratios of the limestone pebbles of different ages in Culm formations shows the decrease of Upper Famennian-Middle Viséan microfacies in the direction from the older part of the Culm (Protivanov Fm.) to its younger part (Myslejovice Fm.). The analyses of the microfauna has shown that the pebbles of the Givetian-Lower Famennian and Middle-Upper Viséan limestones occur in the eastern part of the Drahany Upland only. These trends in the content of the limestone pebbles of various ages and sedimentary environments in individual formations and their areal distribution are interpreted as a result of two processes: 1) progressive erosion of the sedimentary cover of the basement unit from its distal (pelagic and hemipelagic) through proximal (platform) parts due to foreward thrust propagation in the accretionary wedge of the colliding terranes; 2) post-sedimentary tectonic juxtaposition of the western and the eastern parts of the Drahany Culm. An advantage of the microfacial analysis of limestone pebbles is demonstrated for the regions where source-rocks were tectonically modified after their erosion and/or where the source-area was covered with younger sediments.

Key words: Devonian, Lower Carboniferous, Rhenohercynian Zone, Drahany Culm, flysch, tectonic implications, limestone microfacies, limestone pebbles.

Introduction

The Moravosilesian Culm sediments are situated in the easternmost part of the Bohemian Massif and are considered by many authors (e.g. Dallmeyer et al. 1995) to be a part of the southeastern branch of the Rhenohercynian and Subvariscan Zone of the European Hercynides. They represent the sedimentary cover of the Brunovistulicum which is regarded as the continuation of the Eastern Avalonian group of terranes involved in the oblique convergence with the southern peri-Gondwana Lugodanubian group of terranes during the Hercynian orogeny (Kalvoda 1995). Tectonically juxtaposed Devonian and Carboniferous carbonate and flysch sequences are the remnants of different sub-basins developed on the Brunovistulian passive margin.

The Drahany Culm represents the southern part of the flysch development of the Moravosilesian Culm and includes three formations: Protivanov Fm., Rozstání Fm. and Myslejovice Fm. (Dvořák 1973b; Figs. 1 and 2).

In the Protivanov Fm., which consists mainly of shales and greywackes, the "Kořenec Conglomerates" and conglomerates of the "Bouzov Culm" (Fig. 2) have been studied. These polymict coarse-grained conglomerates are strongly deformed and crop out as oblong discontinuous bodies intercalated in greywackes. The Kořenec Conglomerates contain pebbles of Brunovistulian granitoids, while Moldanubian high-grade metamorphic rocks are absent (Štelcl 1965). The content of the basement-derived pebbles is consistent with the $^{40}Ar/^{39}Ar$ ages of some detrital micas which suggests Cadomian cooling of the source-rocks (Schneider et al. 1999). According to Viséan foraminiferal fauna from limestone pebbles of the Kořenec Conglomerates (Kalvoda et al. 1995), we estimate the age of the formation to be from Middle Viséan to lower part of Upper Viséan.

The Rozstání Formation is composed mainly of siltstones with intercalations of fine-grained greywackes and lenticular bodies of medium- to coarse-grained greywackes. Conglomerates are very scarce and crop out in two areas only. Thin layers of deformed conglomerates occur close to localities 12 and 13 in the northern part of the Drahany Upland. Limestone blocks up to several meters in size (olistolithes by Dvořák 1987) are intercalated in shales at locality 15. The age of the formation is estimated to be Upper Viséan according to fauna in the limestone pebbles and to its geological position between the other two Culm formations.

In the Myslejovice Formation conglomerates constitute almost half of the lithology. They predominate in the south while greywackes and shales prevail in the northern part. The older, coarse-grained, polymict Račice Conglomerates with greywacke matrix contain pebbles of Moravian and Moldanu-

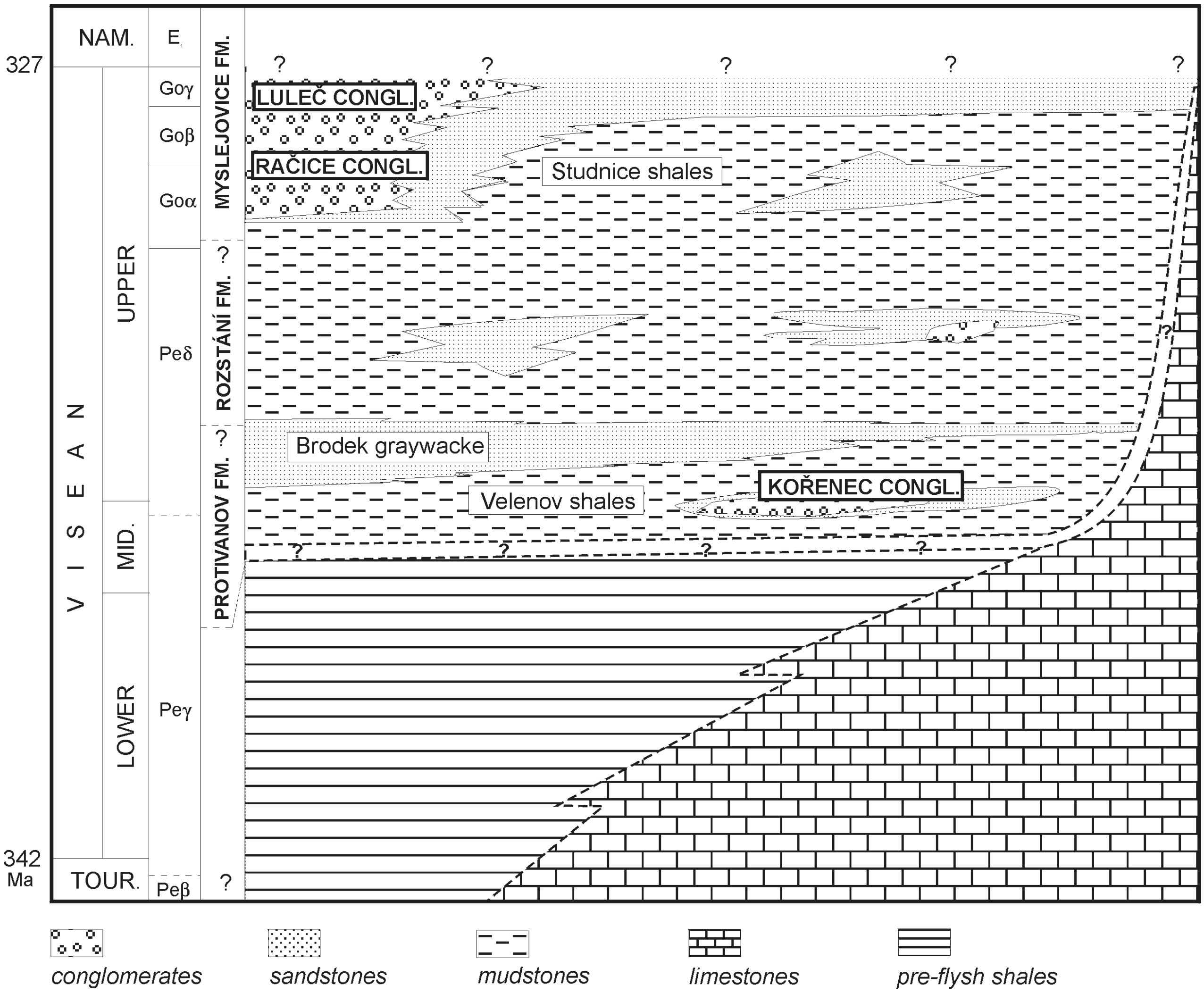

Fig. 1. Stratigraphy of the Drahany Culm.

bian metamorphites and magmatites, older Culm flysch sediments and limestones. This lithology crops out in the west (see Fig. 1). In the top of the conglomerate sequence, a facies known as the Luleč Conglomerates is distinguished which is defined by the distinct content of Moldanubian granulites and gneisses and less common pebbles of magmatic and sedimentary rocks (Štelcl 1960). The transition of heavy minerals assemblages from low and medium grade metamorphic dominant to high grade ultra-metamorphic dominant (Hartley & Otava, in press) together with compositional differences betweeen the pebble material of the Račice and the Luleč types correspond to progressive change in provenance.

The lower portions of the conglomerates contain boulders up to 2 m in diameter, which in most cases are composed of granulites and limestones. Pebbles of both types are mostly well to perfectly rounded. According to the youngest fauna in the limestone pebbles and to the goniatite fauna in the shales, the age of the Myslejovice Formation is considered as Upper Viséan (Peδ to Goγ goniatite zones; Kumpera & Lang 1975; Dvořák 1987).

Inside the Culm flysch sequence, in the Rozstání Formation, a group of several small bodies of pre-flysch rocks crops out (Fig. 1). They are composed mainly of basic volcanites, oolitic iron ores and shales with intercalations of the limestones. According to trilobite and graptolite fauna the shales have been dated as Silurian (Landovery–Ludlow) and Lower Devonian (Emsian). This occurrence of pre-flysch rocks in the middle of the Drahany Culm is interpreted as the boundary-marker of two nappes in the Culm sequence (Chadima & Melichar 1996) on the basis of the model suggested by Cháb (1986) for the northern part of the Moravosilesian Culm.

No direct biostratigraphic data have been obtained from the Rozstání Formation, and only a few data exist from the Protivanov and the Myslejovice Formations. Thus, the limestone pebbles provide a unique source of information on the age of the fossil-free Culm formations which can be indirectly dated by the age of the youngest pebbles. The limestone pebbles also provide some information on the carbonate sedimentary environments, especially on those destroyed during transpressional tectonic phases of the Variscan orogeny. Until now the data on the biostratigraphy and microfacies of the limestone pebbles in the Moravosilesian Culm conglomerates have been rather scattered and are insufficient. In the following pages we summarize the results of our current three-year study on this topic.

Methods

The research was based on detailed microfacial analysis of the limestone pebbles from Culm conglomerates and comparison of their biostratigraphic and other microfacial properties in each formation.

About 140 thin sections from the pebbles of 29 localities represent the input-set for the study (Fig. 2). We attempted to cover the studied area as well as possible with the samples, however, large parts of the Protivanov and the Rozstání Formations still remain without any data. These formations include only rare conglomerate outcrops which are strongly weathered and carbonate pebbles are scarce and often leached. In these two formations all known localities were sampled. In the Myslejovice Fm. the limestone pebbles are rather common and the localities were selected to cover the studied area equally. In each locality all the types of macroscopically distinct limestones were collected, usually in several samples to ensure the completeness of the study. At least two thin sections from every pebble have been analysed.

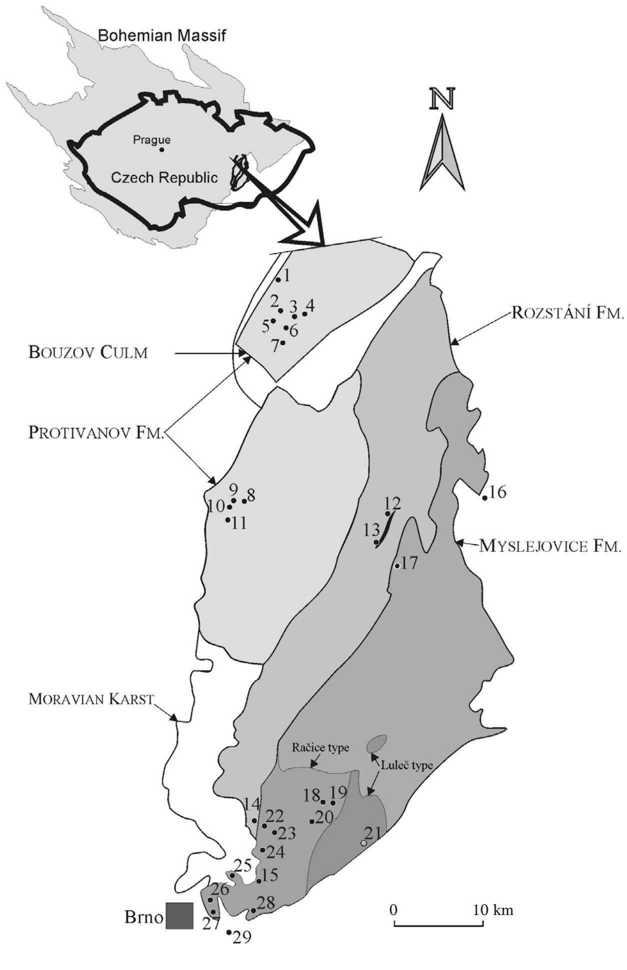

Fig. 2. Schematic map of the studied area with the collection localities. **1** — Vranová Lhota, **2** — Hartinkov II, **3** — Smolná, **4** — Bouzov, **5** — Hartinkov I, **6** — Věžnice, **7** — Trpín, **8** — Kořenec III, **9** — Kořenec II, **10** — Kořenec I, **11** — Okrouhlá, **12** — Ptenský Dvorek, **13** — Stínava, **14** — Křtiny, **15** — Mokrá, **16** — Čelechovice (borehole HJ-3a), **17** — Žárovice, **18** — Oběšený, **19** — Hrádek, **20** — Rakovecké údolí, **21** — Luleč, **22** — Březina, **23** — Hádek II, **24** — Hádek I, **25** — Bělkův mlýn, **26** — Muchova bouda, **27** — Líšeň, **28** — Velatice, **29** — Pindulka. Black body between the localities 12 and 13 — pre-flysch rocks.

The biostratigraphic data, ecology of fossils and the ratio and type of clasts and matrix were used for the description and comparison of the microfacies. An extended Dunham's classification was used for the description of the microfacies (Dunham 1962; Embry & Klovan 1971).

The age determination of limestone pebbles was based mostly on foraminiferal fauna, while the zonation of the Moravosilesian Devonian and Lower Carboniferous strata (Kalvoda 1989) was used for biostratigraphic determinations. Some Devonian microfacies were dated by J. Hladil who analysed corals and stromatoporoids.

The established groups of microfacies with similar features have been interpreted in terms of sedimentary environment and compared with the facies zones of Wilson (1975) (see Fig. 3). This serves only for comparative purposes in the present work and we do not attempt to reconstruct the carbonate platform from which the pebbles derived.

Microfacies

Only a general description of the main types of microfacies is presented in this work. More detailed microfacial characteristics, as well a list of identified fossils, are given in a manuscript of Špaček (1997).

On the basis of the evolutionary stages of foraminiferal assemblages, all the microfacies were classified into four broad age groups (plus the group of uncertain age) and further subdivided into facies types according to structure and component contents. The foraminiferal fauna in thin sections was not always conclusive enough to enable exact identification and often only the biostratigraphic assignment within the range of more zones was possible.

The descriptions of microfacies are ordered according to their importance within the age-based groups:

1) Givetian-Lower Famennian (Giv-Fa1) microfacies are characterized by primitive foraminifers of the Nanicella Zone, Multiseptida corallina-Eonodosaria evlanensis Zone, Eonodosaria evlanensis-Quasiendothyra communis Interzone. Stromatopors *Amphipora* sp., *Dendrostroma* sp., *Stachyodes* sp. and the coral *Coenites* sp. may be present.

Type 1A. Rudstones/floatstones with large clasts of stromatopors and corals. Matrices are wackestones or poorly-washed grainstones composed of pelloids and bioclasts which are often micritized. Primitive foraminifers, ostracods, fragments of molluscs, crinoids and sponge-spicules are present. Small subangular grains of quartz were found. Sorting of these microfacies is usually poor. Stromatopors and corals indicate Late Givetian to Middle Frasnian age (Pl. I: Fig. A).

Type 1B. Spongiostroms with micropellets and calcisphaeres. Rare intraclasts and/or peloids may be present. Fauna is very scarce and thus the age determination is difficult. Primitive foraminifers indicate Givetian to Frasnian age.

Type 1C. Coarse-grained packstones with bryozoans, foraminifers and micritized grains. Some peloids and cal-

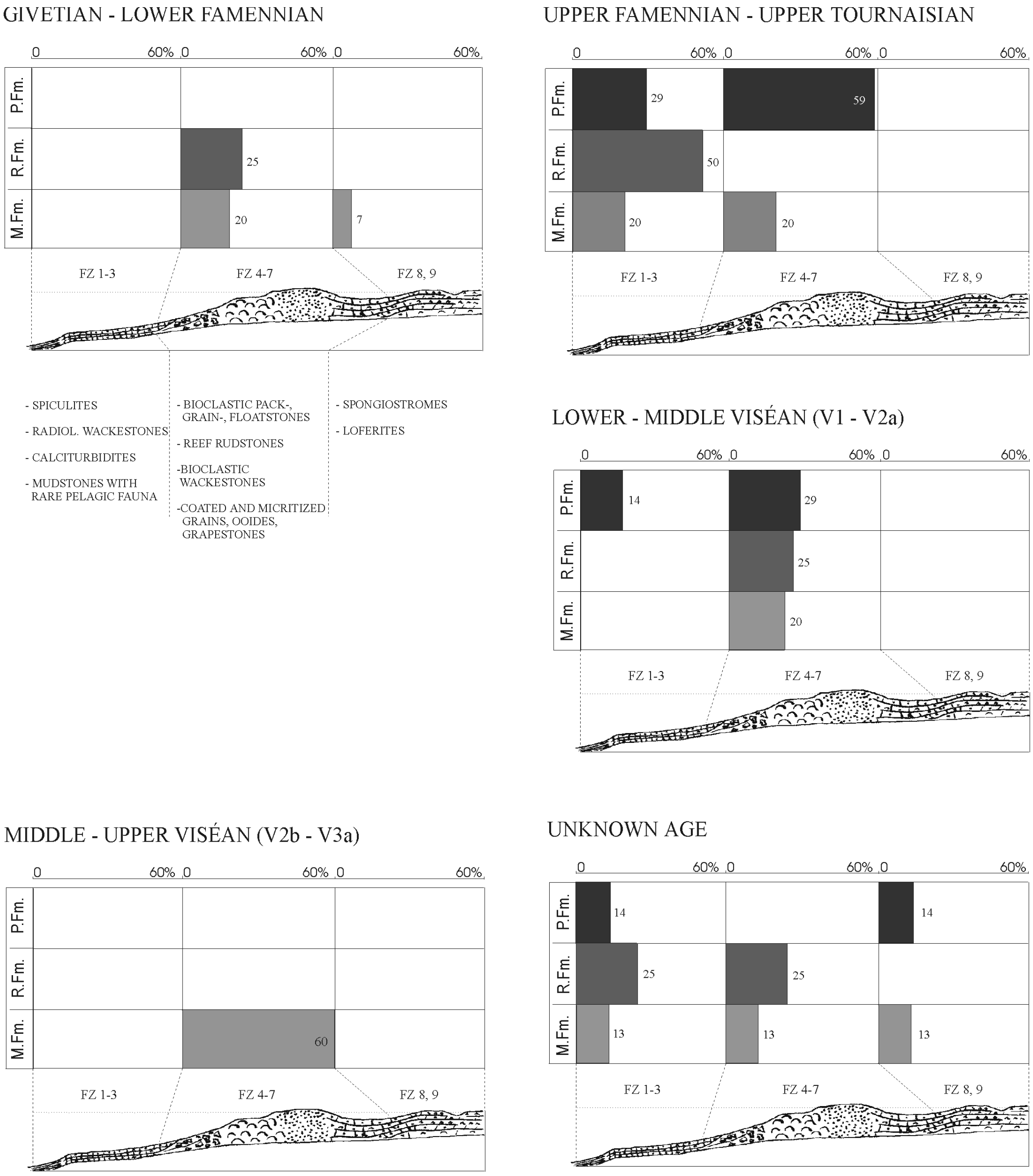

Fig. 3. Representation of the limestone pebbles of the different types of sedimentary environment in individual Culm formations. The expression of the sedimentary environment is simplified by dividing it into the three groups of facial zones of Wilson (1975). The values represent the fraction of localities with the content of microfacies of specific sedimentary environment on total number of localities in the formation. *Explanation of abbreviations:* Fa1, Fa2 — Lower and Upper Famennian, V1a, V1b — lower and upper parts of Lower Viséan, V2a, V2b — lower and upper parts of Middle Viséan, V3a — lower part of Upper Viséan; P.Fm. — Protivanov Formation, R.Fm. — Rozstání Formation, M.Fm. — Myslejovice Formation.

cisphaeres may be present. The foraminifers are of Frasnian to Lower Famennian age.

2) Upper Famennian-early part of Lower Viséan (Fa2-V1a) microfacies contain foraminifers of the Quasiendothyra communis-Q. regularis Zone, Q. kobeitusana-Q. konensis Zone, Chernyshinella glomiformis Zone, Ch. tumulosa–Spinobrunsiina Zone, Paraendothyra Zone, Tetrataxis-Eoparastaffella simplex Zone. *Moravamminidae* indet. is common and the coral *Ortholites* sp. was found in locality 8.

Type 2A. Fine-grained limestones with alternating dark-coloured layers containing radiolarians and packstones of light-grey colours with considerable amount of shallow-water derived bioclasts (mainly echinoderms, foraminifers and green algae), peloids and small quartz clasts. Rarely erosional surfaces of dark wackestones, sub-horizontal lamination and less pronounced normal gradation can be observed. The foraminifers of the packstone layers indicate Late Famennian to latest Tournaisian age (Pl. II: Fig. C).

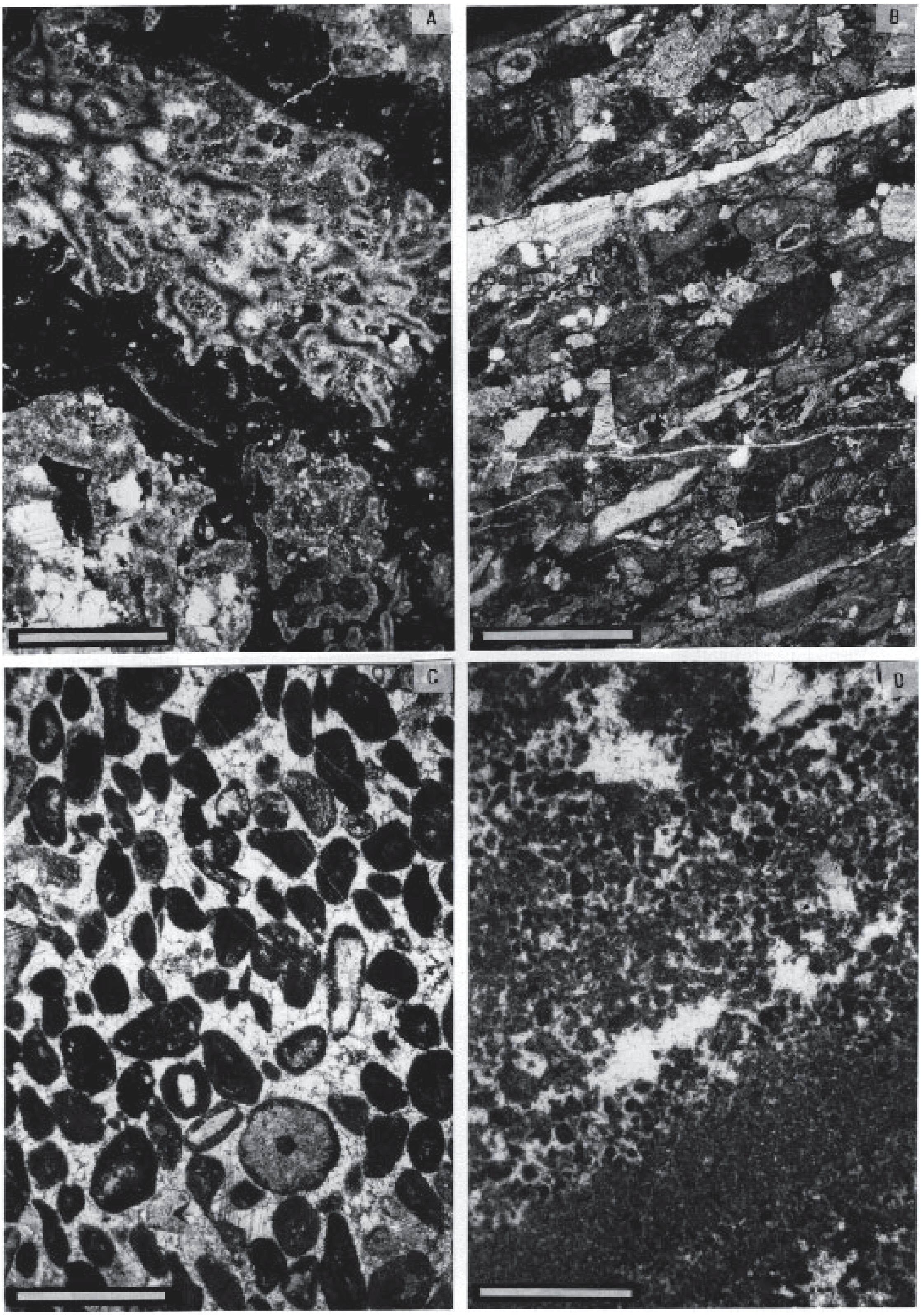

Plate I: Microfacies of limestone pebbles in the Drahany Culm. Scale 1 mm. **A** — Floatstone/rudstone with broken stems of amphipors (*Amphipora pervesiculata* (Lecompte), *A. laxeperforata* (Lecompte)). In the micrite matrix foraminifers, *Moravamminidae* indet., sponge spicules and the detritus of fine bioclasts occur. Middle Frasnian, loc. 25, Myslejovice Fm.; **B** — Packstone with peloids, intraclasts, bioclast and non-carbonate clasts (quartz, clastic sedimentary rocks). *Moravamminidae* indet., *Dasycladaceae* indet., conodonts? are present. Some foraminifers occur within the intraclasts. Uppermost Tournaisian–Lowermost Viséan (Tetrataxis-Eoparastafella simplex Zone), loc. 5, Protivanov Fm.; **C** — Grainstone with peloids and echinoderms. Well-sorted, well-washed with micritized bioclasts, rare quartz grains and foraminifers in sparite matrix. Upper Famennian–Lower Viséan (Quasiendothyra kobeitusana-Q. konensis Zone), loc. 5, Protivanov Fm.; **D** — Spongiostromes with small pseudopellets in thin laminar beds. Unknown age, loc. 27, Myslejovice Fm.

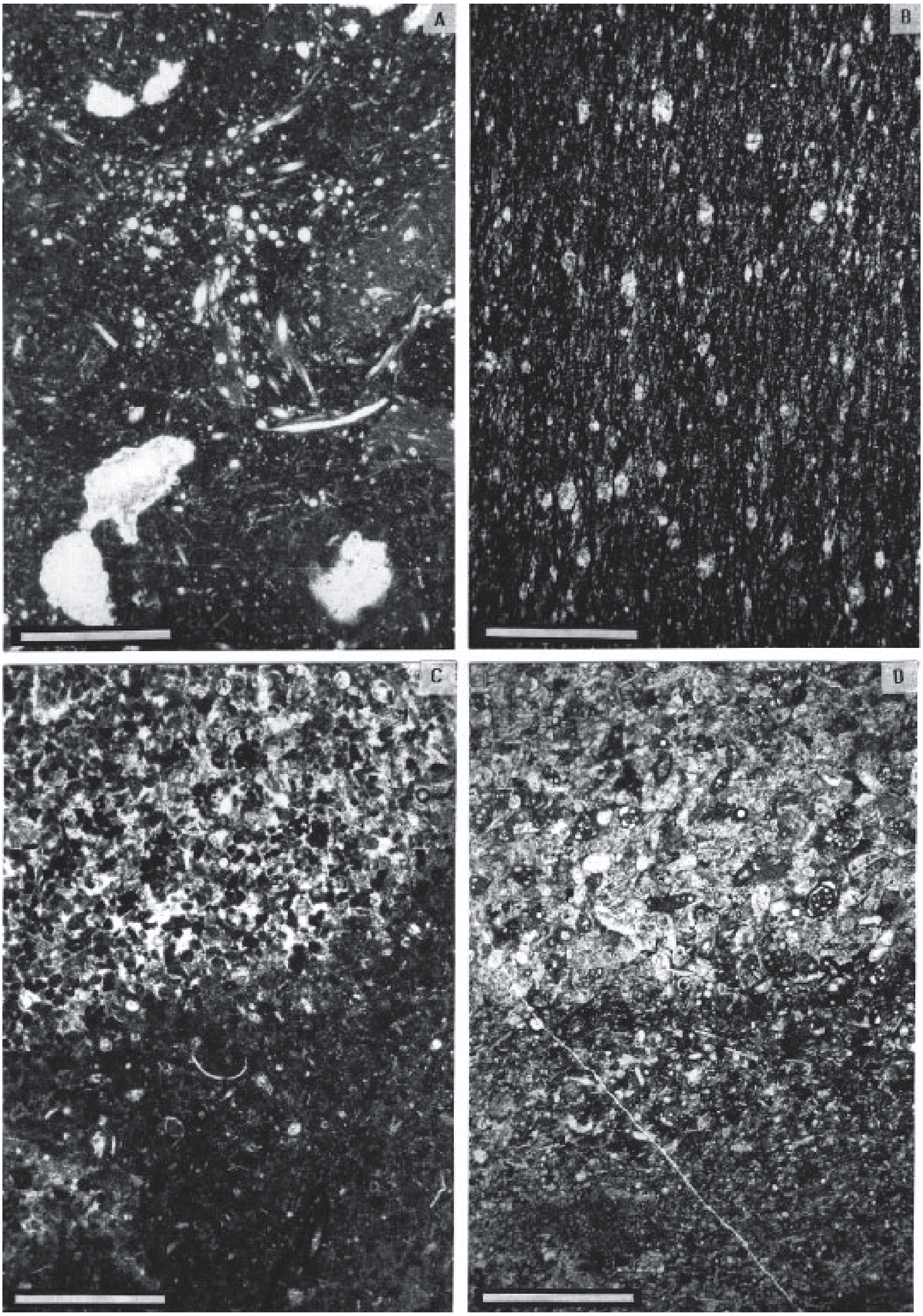

Plate II: Microfacies of limestone pebbles in the Drahany Culm. Scale 1 mm. **A** — Spiculite. The holes perforated by worms are filled with sparite cement. Unknown age, loc. 24, Myslejovice Fm; **B** — Radiolarian wackestone, tectonically deformed, darker domains are enriched in clays due to solution at foliation surfaces. Unknown age, loc. 2, Protivanov Fm.; **C, D** — Two examples of facies interpreted as calciturbidites. Rapidly changing layers of darker wackestones with radiolarians and packstones with foraminifers, small peloids and fine-grained debris of bioclasts. In some thin sections gradation is visible; C — Upper Famennian–Lower Tournaisian, loc. 15, Rozstání Fm.; D — uppermost Lower Viséan–lowermost Middle Viséan (Viseidiscus eospirillinoides-Glomodiscus oblongus Zone), loc. 15, Myslejovice Fm.

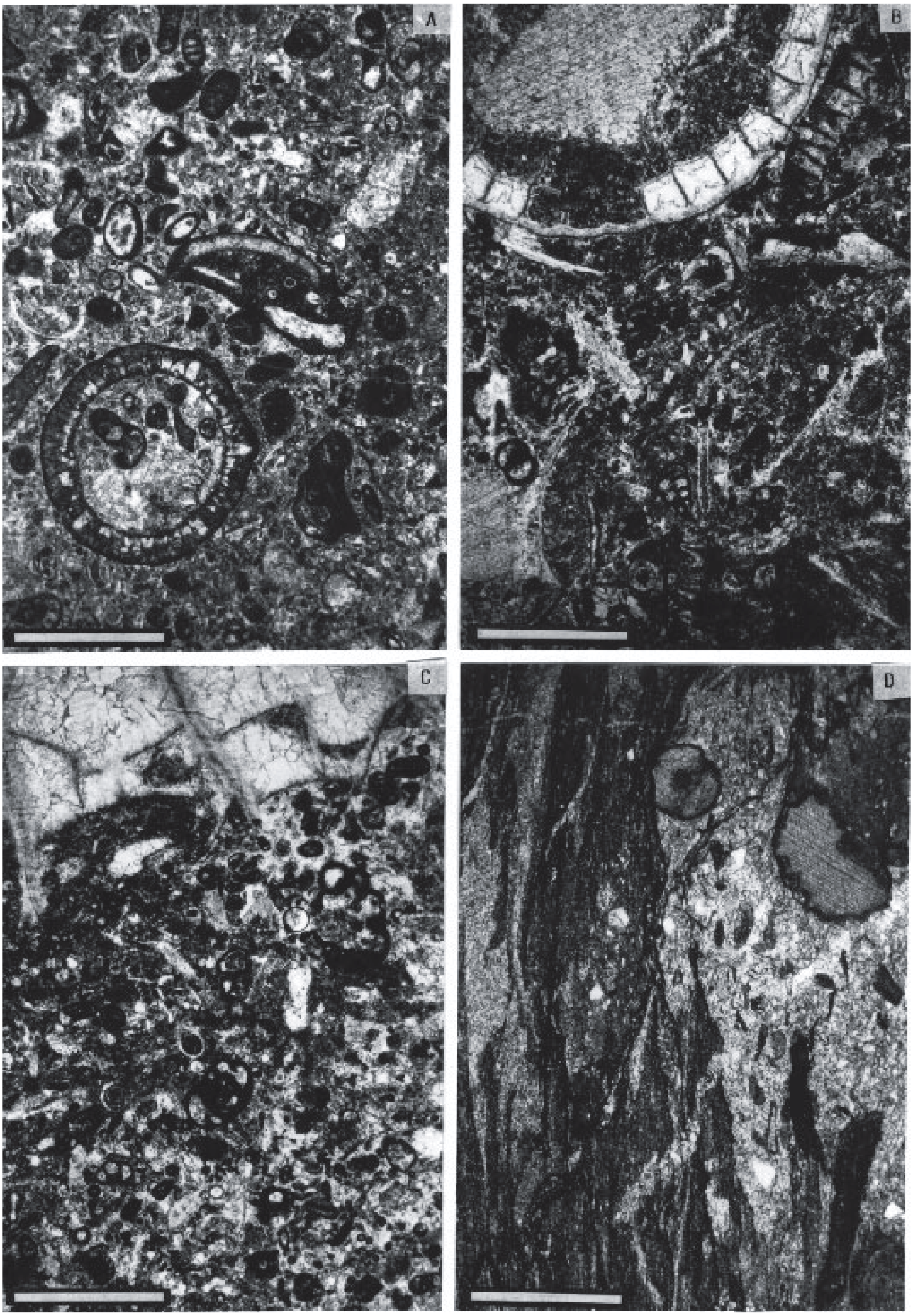

Plate III: Microfacies of limestone pebbles in the Drahany Culm. Scale 1 mm. **A, B, C** — Examples of lagoonal packstones/rudstones/floatstones with foraminifers, green algae — *Koninckopora* sp., corals, echinoderms, bryozoans, brachiopods and other bioclasts, some of which are covered and/or aggregated. Uppermost Middle Viséan–lowermost Upper Viséan (Pojarkovella nibelis-Koskinotextularia Zone), loc. 15 (A), 26 (B), 29 (C); **D** — Typical tectonically deformed facies of Protivanov Fm., originally packstone with crinoids. Unknown age, loc. 9.

Type 2B. Packstones with intraclasts, ooids, peloids and clasts of shallow-water biota. Bioclasts are represented by echinoderms, bryozoans, foraminifers, green algae, corals, gastropods and ostracods. In some microfacies clasts of quartz, siliciclastic sediments and feldspar are of significant content. Some microfacies with a lower content of bioclasts (wackestones) of slightly different constitution (abundant ostracods and calcisphaeres) were added to this group. Foraminiferal assemblages indicate Late Famennian to latest Tournaisian or earliest Viséan age (Pl. I: Fig. B).

Type 2C. Mudstones and wackestones with scarce clasts of sponge-spicules, thin-shelled bivalves, ostracods. Rare foraminifers indicate Late Famennian to latest Tournaisian age.

Type 2D. Peloidal grainstones with micritized crinoids. These grainstones are always well-sorted and well-washed. In some grainstones of this type scarce foraminifers were found, which indicate Famennian to earliest Viséan age (Pl. II: Fig. C).

3) Lower Viséan–base of Middle Viséan (V1b-V2a) microfacies contain foraminifers of the Viseidiscus eospirillinoides-Glomodiscus oblongus Zone. *Moravamminidae* indet., and *Koninckopora* sp. are common.

Type 3A. In this group microfacies similar to those from group 2B are incorporated. These are packstones/rudstones and poorly washed grainstones with bioclasts of various mainly shallow-water organisms (echinoderms, foraminifers, calcisphaeres, ostracods, green algae, bryozoans, brachiopods). Frequently peloids and quartz clasts are present.

Type 3B. Limestones with alternating fine-grained dark-coloured layers and coarse-grained bioclast-rich layers. Microstructures and bioclastic content of these microfacies are very similar to those of the type 2A (Pl. II: Fig. D).

The age of Lower Viséan to base of Middle Viséan was determined on the basis of foraminiferal assemblages in both 3A and 3B groups.

4) Upper part of Middle Viséan–base of Upper Viséan (V2b-V3a) microfacies contain foraminifers of the Pojarkovella nibelis-Koskinotextularia Zone and abundant *Koninckopora* sp., *Stacheiinae* indet., *Gigantoproductus* sp.

Type 4A. Packstones, rudstones and wackestones with foraminifers and green algae predominating. In addition to the main bioclastic constituents frequent crinoids, brachiopods, bryozoans, trilobites, ostracods, corals, intraclasts and lumps are present. No terrigenic material was observed in the microfacies of this type (Pl. III: Figs. A, B, C).

Type 4B. Algal coverstones. Irregular intercalations of packstones contain scarce foraminifers, ostracods, crinoids and bivalves. Sparite-filled fenestral vugs are frequent.

Type 4C. Grainstones with ooids, peloids and foraminifers. Lumps, intraclasts and fragments of micritized crinoids, brachiopods, algae, gastropods are present. Grainstones of this type are well-washed and poorly sorted.

The age V2b–V3a of all the specimens was determined on the basis of foraminiferal assemblages.

5) Microfacies of unknown age were divided into three main groups:

5A. Wackestones, packstones and poorly washed grainstones with various components (ostracods, algae, intraclasts, micritized grains, peloids, crinoids, foraminifers) (Pl. III: Fig. D).

5B. Spongiostroms with algal fabric, calcisphaeres, micropseudopellets, rare bioclasts and quartz (Pl. I: Fig. D).

5C. Dark mudstones and wackestones with calcified radiolarians and sponge spicules (Pl. II: Figs. A, B).

Sedimentary environment

The interpretation of sedimentary evironment was limited by the fact that pebbles always represent only a small part of a sedimentary sequence, which is extracted from its context and thus gives only limited information on sedimentological aspects. It is then very difficult to determine the depositional conditions of the rock. All the interpretations of the depositional environment given in the following paragraphs are based on the comparison of the microfacies of pebbles with those of better known sequences and should be considered as the most probable alternatives.

The most shallow-water facies are spongiostromatic limestones of the types 1B and 5B and the coverstones of the type 4B. They are interpreted as algal mats of peritidal environments. The activity of microbial organisms is apparent from frequent micropellets. Fenestral vugs indicate dessication processes and scarce biodetritic intercalations can be explained as a product of channel migration.

Facies of high-energy environments are represented by grainstones of the types 2D and 4C. Constant wave and/or current action is indicated by well to perfectly rounded grains and lack of micrite in inter-grain space.

Packstones/rudstones of the types 1C, 2B, 3A, 4A and 5A represent a widespread assemblage of deposits from protected lagoon environments. Abundant micrite indicates low dynamics of water, while common green algae, peloids and micritized grains suggest a shallow-water origin for these types of facies. Small transport is indicated by rather bad sorting of the bioclasts.

Rudstones/floatstones of the type 1A have probably been deposited in close proximity to a reef. The fossils are well preserved and display short transport from their original position. Micrite matrix indicates low wave energy of the sedimentary environment.

Facies of the types 2A and 3B are interpreted as parts of calciturbidite sequences. T_b, T_c and T_d Bouma divisions were observed. Generally, these facies types are very similar to those described in well exposed outcrops of southern part of the Moravian Karst (Kalvoda et al. 1996).

Pelagites are represented by radiolarian wackestones and spiculites of 5C type. Mudstones/wackestones of the type 2C with scarce thin-shelled bivalves are also interpreted as deep-sea sediments.

Results

Protivanov Formation

In view of the sedimentary environment of the limestone pebbles, the wide spectrum of facies is characteristic of conglomerates of the Protivanov Formation.

Deeper-water facies prevail — mudstones and wackestones with radiolarians and sponge-spicules are relatively common (type 2C, 5C, localities 1, 2, 7 and 8). Microfacies very similar to calciturbidites were found (type 2A, loc. 5).

Shallow-water microfacies are represented by spongiostroms (type 5B, loc. 7), lagoonal packstones with foraminifers, peloids, echinoderms (types 2B and 3A, localities 5, 6, 7, 8 and 11) and by well-washed, well-sorted grainstones (2D, loc. 5).

Generally, microfacies of limestone pebbles in the Protivanov Fm. are very poor in foraminifers and they contain no green algae at all. The pebbles of these conglomerates were strongly deformed, which makes their analysis more difficult. The age of the limestone pebbles in the Protivanov Fm. ranges from Late Famennian to Early–Middle Viséan (Fig. 4).

Rozstání Formation

The Rozstání Formation is very poor in conglomerates. Only five localities in the northern and southernmost parts of the formation could be sampled.

In the northern part of the formation (locality 11) Frasnian lagoonal facies of peloid-coral floatstones (type 1A) and lagoonal facies of unknown age (type 5A) were found. Facies from a deeper environment represented by radiolarian wackestones (type 5C) were found at locality 13.

In the southernmost part (loc. 15) calciturbidites and hemipelagic microfacies of Upper Famennian to lowermost Middle Viséan age are characteristic (similar microfacies as in the Protivanov Fm., alternating wackestones and packstones with radiolarians, foraminifers etc., type 2A).

At locality 14 the pebbles of higher Middle Viséan to lower Upper Viséan were described by Dvořák (1973a).

The pebbles studied in the conglomerates of the Rozstání Formation are of Frasnian–Middle Viséan age; but Tournaisian limestone pebbles prevail (Fig. 4).

Myslejovice Formation

In the pebbles of the conglomerates of the Myslejovice Fm., microfacies interpreted as shallow-water platform sediments of Middle–Late Viséan (V2b–V3a) age are strongly prevalent. This group is represented by foraminiferal-algal packstones, rudstones and floatstones with corals, intraclasts and other bioclasts (type 4A, in less amounts types 4B and 4C, localities 15–18, 21, 23, 25, 27 and 29). Givetian to Frasnian shallow-water facies of similar type are abundant as well: foraminiferal-algal packstones, rudstones and floatstones with stromatoporoids (1A, loc. 23 and 25), packstones with bryozoans, foraminifers and micritized grains (1C, loc. 19), spongiostroms (1B, loc. 16 and 27). Some of these microfacies contain substantial amounts of nectonic fauna (trilobites, conodonts) and could represent deeper-water sediments with clasts partially resedimented.

Facies of the Famennian to Lower-Middle Viséan limestones are more differentiated in terms of the depositional environment. Lagoonal packstones, grainstones and rudstones with foraminifers and algae prevail (mainly types 2B and 3A, loc. 15, 18, 22, 25, 28 and 29), but also facies interpreted as calciturbidites are abundant (type 2A, loc. 15, 18 and 25). In the microfacies of undetermined age both the shallow-water (e.g. spongiostroms, type 5B, loc. 23) and deeper-water types were found (e.g. spiculites, type 5C, loc. 24).

The age of the pebbles in the Myslejovice Fm. ranges from Givetian to Late Viséan (Fig. 4).

An apparent divergence in the content of the limestone pebbles of various ages in individual formations is illustrated in Fig. 4. Comparing the relative amount of the pebbles of all four time intervals in each formation, we can see the increase in the number of Givetian-Lower Famennian and Middle-Upper Viséan (V2b–V3a) and the decrease of the Upper Famennian-Middle Viséan limestones in the direction from older to younger formations (from the Protivanov Fm. to the Myslejovice Fm.).

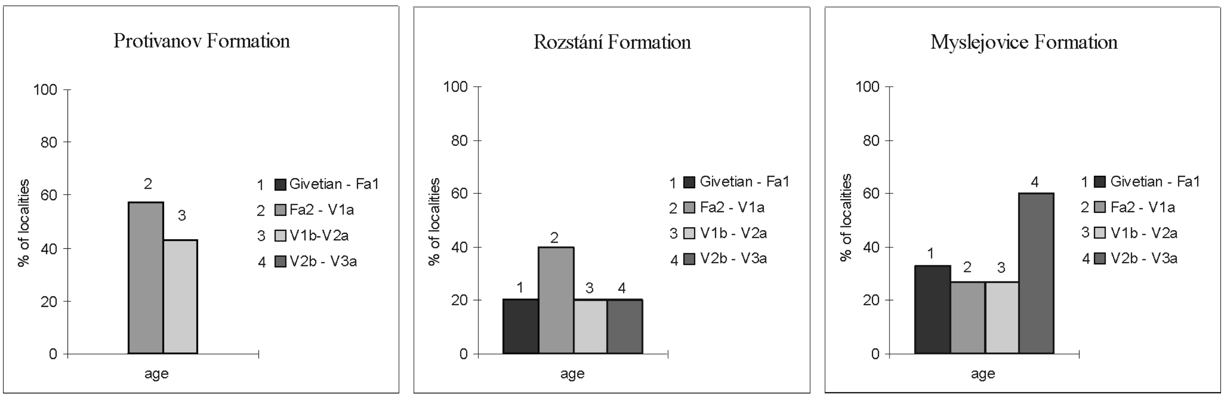

Fig. 4. Representation of the limestone pebbles of the different time intervals in each formation. The values represent the fraction of localities containing pebbles of a specific age-range to the total number of localities in the formation. Localities which contained only the pebbles of uncertain age were not included in the calculation. The pebbles of the age V2b–V3a described by Dvořák (1973a) is concluded in the chart as well. For explanation of abbreviations see Fig. 3.

Interpretation and discussion

A comparison of the content of the limestone pebbles of various ages in individual formations illustrated in Fig. 4 indicates that the erosional history of the source area of Givetian-Lower Famennian (time interval 1) and Middle-Upper Viséan limestones (time interval 4) was similar and that the source area of the Upper Famennian–base of Middle Viséan limestones had a different erosional development.

The areal distribution of the pebbles of the time intervals 1 (the oldest pebbles) and 4 (the youngest pebbles) is the same and differs from that of the pebbles of the time intervals 2 and 3 (Fig. 5). The pebbles of Givetian-Lower Famennian and Middle-Upper Viséan limestones occur in the eastern part of the Drahany Upland only. This distribution shows some differences in the source area of the western and the eastern parts of the Drahany Culm.

A combination of the two possible interpretations can be inferred:

1) Assuming a simple model for the passive margin of the Brunovistulicum and foreward thrust propagation in the accretionary wedge of the colliding terranes, the compositional trend of the limestone-pebble material suggests progressive erosion of the sedimentary cover of the basement unit from its distal (pelagic and hemipelagic) to proximal (platform) parts. Both the oldest (Giv-Fa1) and the youngest (V2b-V3a) carbonates represent platform facies and thus their predominance in proximal parts of a passive margin is expected.

2) The correspondence of the westernmost external occurrences of the youngest and the oldest limestone pebbles with the belt of the occurrence of pre-flysh Silurian and Devonian rocks is apparent. The sharp compositional difference between the both parts of the Culm can be therefore explained as a result of their different original position within the Culm basin (Western and Eastern Culm units of Cháb 1986).

An insufficient volume of data can distort the statistical results, as in the case of localities 16 and 17. Here only a few of the samples collected during former studies were analysed, which is probably the reason why the Upper Famennian-Lower Viséan and Lower-Middle Viséan limestone pebbles do not appear in the northeastern part of the Myslejovice Fm. (Fig. 5).

Provenance studies are complicated by the imperfect knowledge of the tectonic development in the Variscan collisional area. We suppose that the depositional area of the main amount of limestones was situated on the Brunovistulian passive margin. Paleocurrent analysis, which revealed the main direction of transport from S-SW to N-NE in the flysch basin (Kumpera 1966), supports the idea of dominant supply from hinterland. Nevertheless, some features of the Culm sediments seem to be in contrast to the hinterland-source model:

1) dominant content of the pebbles of the youngest (V2b-V3a) limestones in the Myslejovice Formation. These facies are very scarce in a region, which is to the west (i.e. in the hinterland part) of the Drahany Culm and they predominate in the foreland of the Variscan orogeny (e.g. Dvořák 1987).

2) the lack of the penetrative tectonic deformation of the limestone pebbles. In the westernmost part of the Drahany Culm the most of the limestone pebbles are ductily deformed, but this seems to be due to the strong post-Culm dextral shear of the flysh rocks (Špaček 1999). Even in the youngest Culm conglomerates, the pebbles of the strained limestones have never been found.

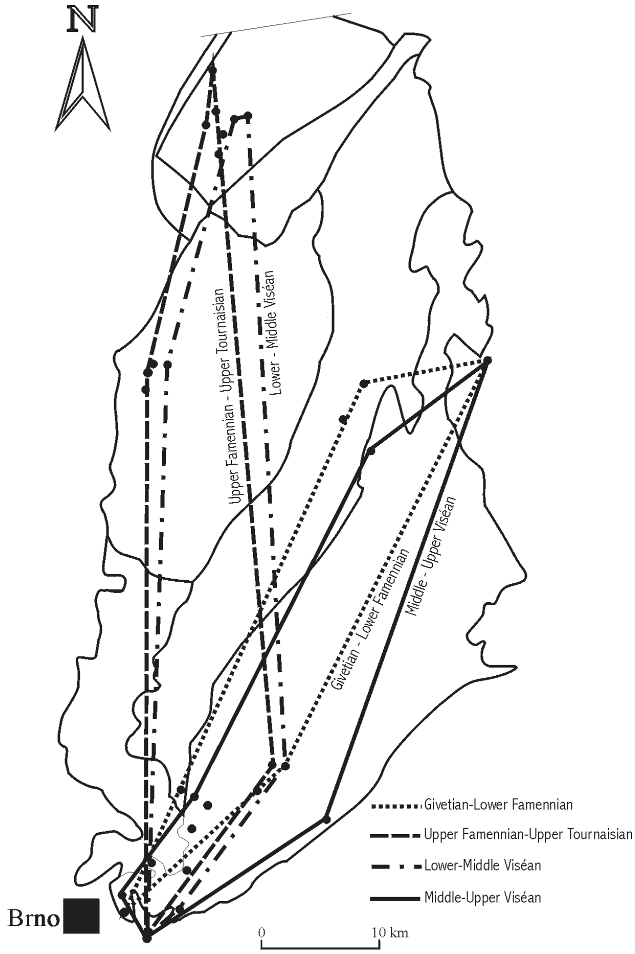

Fig. 5. Areal distribution of the limestone pebbles of different age. The scatter-fields of localities with content of pebbles of specific age-range are contoured by different lines. For explanations of the map see Fig. 2.

Another problem in the interpretations of provenance is associated with the significant content of the Cadomian clastic material in the Protivanov Formation. The underplating basement of the Brunovistulicum was probably the source of this material. This fact can reflect that the tectonic imbrication of the underthrusting plate was not strictly superficial and affected even deeper parts in a footwall of the sedimentary cover.

For the better understanding of the provenance, detailed re-evaluation of the paleocurrent data and complex pebble analysis must be carried out in the future research.

The size of the largest limestone pebbles in the Myslejovice Formation is very similar to that of granulite pebbles, which were undoubtedly transported from the hinterland. These pebbles are up to 2 meters in diameter and their origin surely required much higher elevations than can be expected during forebulging. Generally well to perfectly rounded limestone pebbles strongly prevail. Nevertheless, some large limestone pebbles were found which have rather angular to subangular shape. These are, in contrast to the perfectly rounded pebbles, always of Upper Famennian–base of Middle Viséan age, which supports the idea that the pebbles of the two groups (time intervals 1+4 vs. 2+3) were derived from different sources.

Provenance change related with the apparent petrographic differences between the Račice and the Luleč Conglomerates of the Myslejovice Formation is not reflected in a composition of the limestone pebbles. Nevertheless, in these conglomerates the content of the limestone pebbles is very small and the quick uplift of the hinterland source-area is apparent from pebble lithology.

The latest research of the pebble material in the Luleč (J. Leichmann, pers. comm.) reveals the presence of very high-grade granulites with late Viséan cooling ages. Similarly, $^{40}Ar/^{39}Ar$ ages of the youngest detrital micas from the upper portions of the Myslejovice Formation show the cooling of their source-rocks through 350–420 °C at 325 Ma (D. Schneider, pers. comm.). The Luleč Conglomerates pass laterally into fossiliferrous shales with goniatites of the Goγ zone (Dvořák 1987). This means that Moldanubian rocks must have been uplifted, exhumed and eroded into Culm basin within extremely short time span, which does not allow significant resedimentation process in the flysh basin, at least for its youngest formation.

Conclusions

The content of the limestone pebbles of different sedimentary environments in all the Culm formations shows a pronounced change in the sedimentation regime of Rhenohercynian carbonates in the Famennian. For the time intervals 2 and 3 (Late Famennian–base of Middle Viséan) the ratio of facies which are interpreted as calciturbidites, hemipelagites and pelagites to the other microfacies rises significantly in all Culm formations of the Drahany Upland. The age of the deep-sea facies of the pebbles correlates well with the interval of maximum extension and the beginning of transtension on the passive Brunovistulian margin when widespread calciturbidite sedimentation occurred in this region (Kalvoda 1995, 1997). There were no such facies found in the pebbles dated as Givetian–Early Famennian and Middle–Late Viséan.

The analysis of the microfauna has shown that the pebbles of Givetian-Lower Famennian and Middle-Upper Viséan limestones occur in the eastern part of the Drahany Upland only. Differences in the content of the limestone pebbles of various ages in individual formations and their areal distribution are interpreted as a result of the two processes:

1) progressive erosion of the sedimentary cover of the basement unit from its distal (pelagic and hemipelagic) through proximal (platform) parts due to foreward thrust propagation in the accretionary wedge of the colliding terranes;

2) post-sedimentary tectonic juxtaposition of the western and the eastern parts of the Drahany Culm. The border and the extent of these two parts seems to correspond to the supposed nappe units of Chadima & Melichar (1996).

In contrast to the distribution of the limestone pebbles, the analysis of heavy minerals assemblages doesn't show any distinctive differences between these two parts of the Culm (Hartley & Otava, in press). Thus, microfacial analysis of limestone pebbles seems to be very helpful, mainly for the regions where crystalline rocks of the source-areas are of similar mineralogical composition.

As far as the provenance is concerned, many features of the Culm flysh basin are contrasting and even the basic questions as e.g. hinterland- vs. foreland-supply model can not be answered unambiguously. In the future research, mainly the source-model for the pebbles of the Cadomian granitoids and for the youngest limestone pebbles should be presented.

Acknowledgements: The authors wish to express their gratitude to J. Leichmann for stimulating discussions and J. Hladil for the determination of Devonian macrofauna. J. Norris and all the reviewers are acknowledged for helping to make the manuscript suitable for publication.

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