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Comparison of the Variscan – Early Alpine evolution of the Jadar Block (NW Serbia) and „Bükkium" (NE Hungary) terranes; some paleogeographic implications

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Abstract. The Variscan and Early Alpine evolution of the Jadar Block (NW Serbia) and „Bükkium" (NE Hungary) terranes are compared showing numerous obvious similarities such as marine development of Carboniferous and Permian (discovery of Paleotethyan fusulinids of Carboniferous age), presence of the Bobova Breccia (as equivalent of the Tarvis Breccia), identical development of Middle and Upper Permian and continual transition to Lower Triassic, Anisian dolomites with the unit of Sebesvíz-type conglomerate on top, early rift volcanism in Ladinian, etc. The Variscan and Early Alpine evolution of the both terranes is also comparable in part to that of the Carnic Alps (Austria, Italy).

Key words: Variscan-Early Alpine evolution, lithostratigraphy, Jadar Block (NW Serbia) and „Bükkium" (NE Hungary) terranes, Carnic Alps.

1. Introduction

The aim of the comparison of the Jadar Block (NW Serbia) and „Bükkium" (NE Hungary) terranes is to establish the similarities and the differences in their geologic development during Variscan and Early Alpine evolution and to show the similarities with coeval successions of the classic localities of Carnic Alps. The correlation of the „Bükkium" Terrane with the latter had already been previously published (Ebner et al., 1991, 1998).

The great similarity between the Jadar and Bükk Late Paleozoic successions was already recognized by Schréter (1948), who mentioned the presence of the „Jadar facies" in the Bükk Mts. Schréter (1959) correlated the Upper Permian, whereas Balogh (1964) both the fossiliferous Carboniferous and Permian sequences of the two areas, within the wider context of the comparison of the Bükk and the Dinarides.

The first Yugoslav geologists to mention similarities in the development of Upper Permian sediments of the Jadar region and Bükk Mts. were Ramovš et al., 1986. Later, in co-operation with Hungarian geologists, Pešić et al. (1988), considering the position of Upper Permian deposits of the Jadar region as part of Western Paleotethys, presented details on the development of the Upper Permian of the Jadar region and on the correlation with similar sediments of the Bükk Mts.

In this paper considerations of the relationships between the Jadar Block and the „Bükkium" terranes during the Variscan and Early Alpine evolution are analyzed in detail. The main characteristics were already given by Filipović et al., 1998.

The relative paleogeographic position of the compared units within the western Paleotethyan and Neotethyan domains is analyzed in a preliminary fashion.

2. General geological setting

Geographically the Jadar Block Terrane is located at the southern and the „Bükkium" Terrane at the northern margin of the Pannonian Basin. In spite of their present separation they both represent crustal fragments which had a very similar, i.e. equivalent geologic evolution during the Late Paleozoic and Early Mesozoic. Their present geologic position (as wedges stuck into geologically different surroundings) was achieved by (Late Cretaceous-) Tertiary strike-slip movements. Today they are isolated geotectonic units within the Vardar Zone Composite Terrane (Jadar Block) and the Pelsonia Composite Terrane („Bükkium") (Fig. 1).

The Jadar Block, as an exotic block terrane displaced into the Vardar Zone in the Upper Cretaceous, is surrounded on three sides by Vardar Zone Composite Terrane members. In the southwest it is thrusted over the Vardar Zone units, while in the southeast the relationships are opposite. Other margins are covered by Tertiary deposits and their contacts cannot be studied, except in the west, where a N-S stretching fault can be assumed as the block boundary (Filipović & Knežević, in Karamata et al., 1994). The differences with the Vardar Zone Composite Terrane are a lack of data on post-Liassic, as well as an absence of ultramafites, ophiolitic mélange, and of Cretaceous flysch development in the Jadar Block Terrane (Filipović, 1995).

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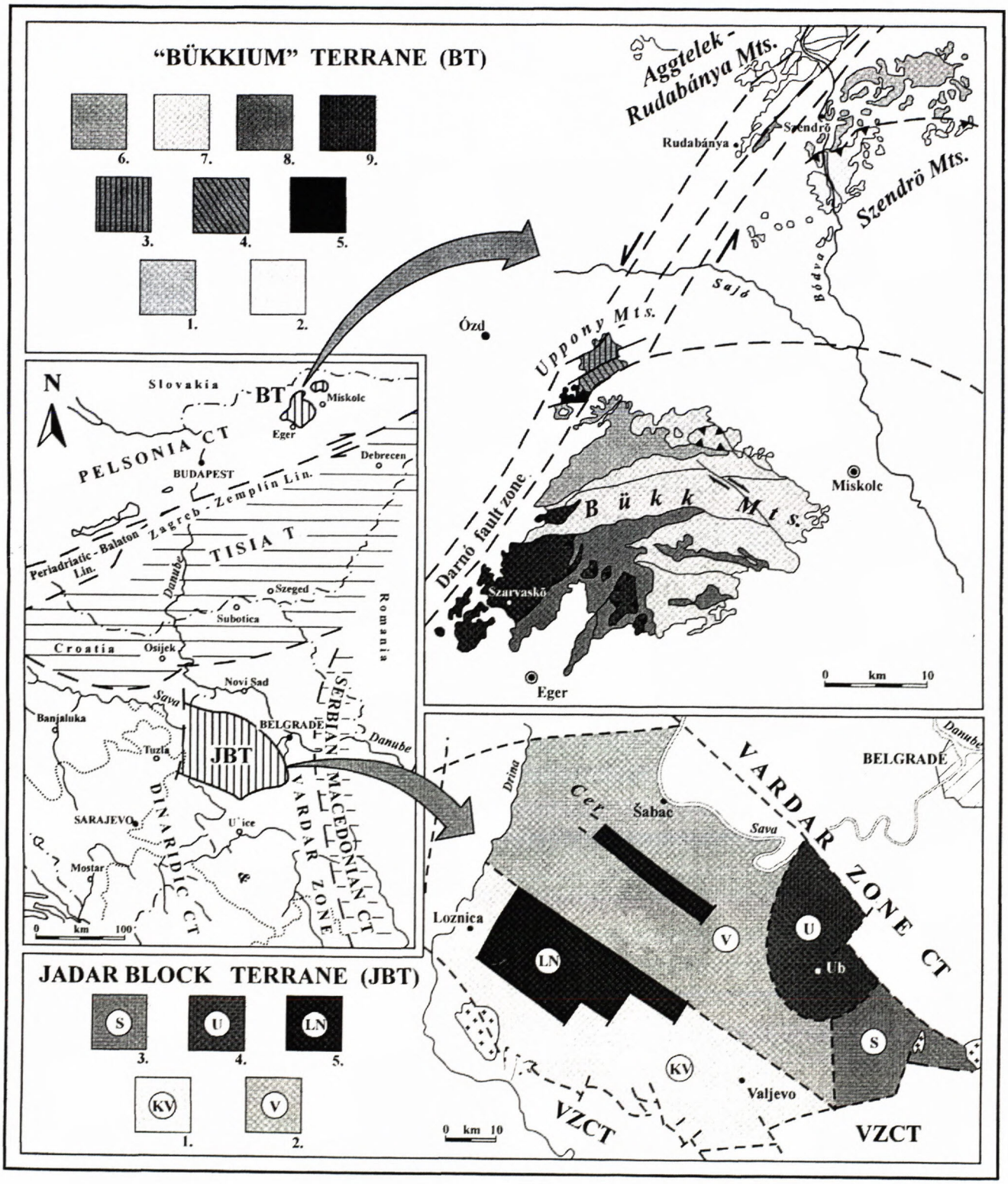

Fig. 1 Sketch of the geographic and present geologic position of the Jadar Block and „Bükkium" terranes within the Circum-Pannonian region and their simplified geologic maps.
Legend. Jadar Block Terrane, Units of the Jadar Autochthon: 1. KV – Krupanj-Valjevo, 2. V – Vlašić, 3. S – Slovac, 4. U – Ub; Jadar Allochthon: 5. LN – Likodra Nappe. „Bükkium" Terrane: 1, 2. Szendrő Unit: 1. Rakaca Subunit, 2. Abod Subunit; 3 – 5. Uppony Unit + Uppony – type Paleozoic in the Rudabánya Mts.: 3, 4. Uppony Paleozoic: 3. Lázbérc Subunit, 4. Tapolcsány Subunit, 5. Gosau-type Senonian conglomerate in the Uppony Mts.; 6 – 9. Bükk Mts.: 6 – 8. Bükk PA: 6. Upper Paleozoic, 7. Triassic, 8. Jurassic; 9. Szarvaskő-Mónosbél Nappe of the Bükk Mts.

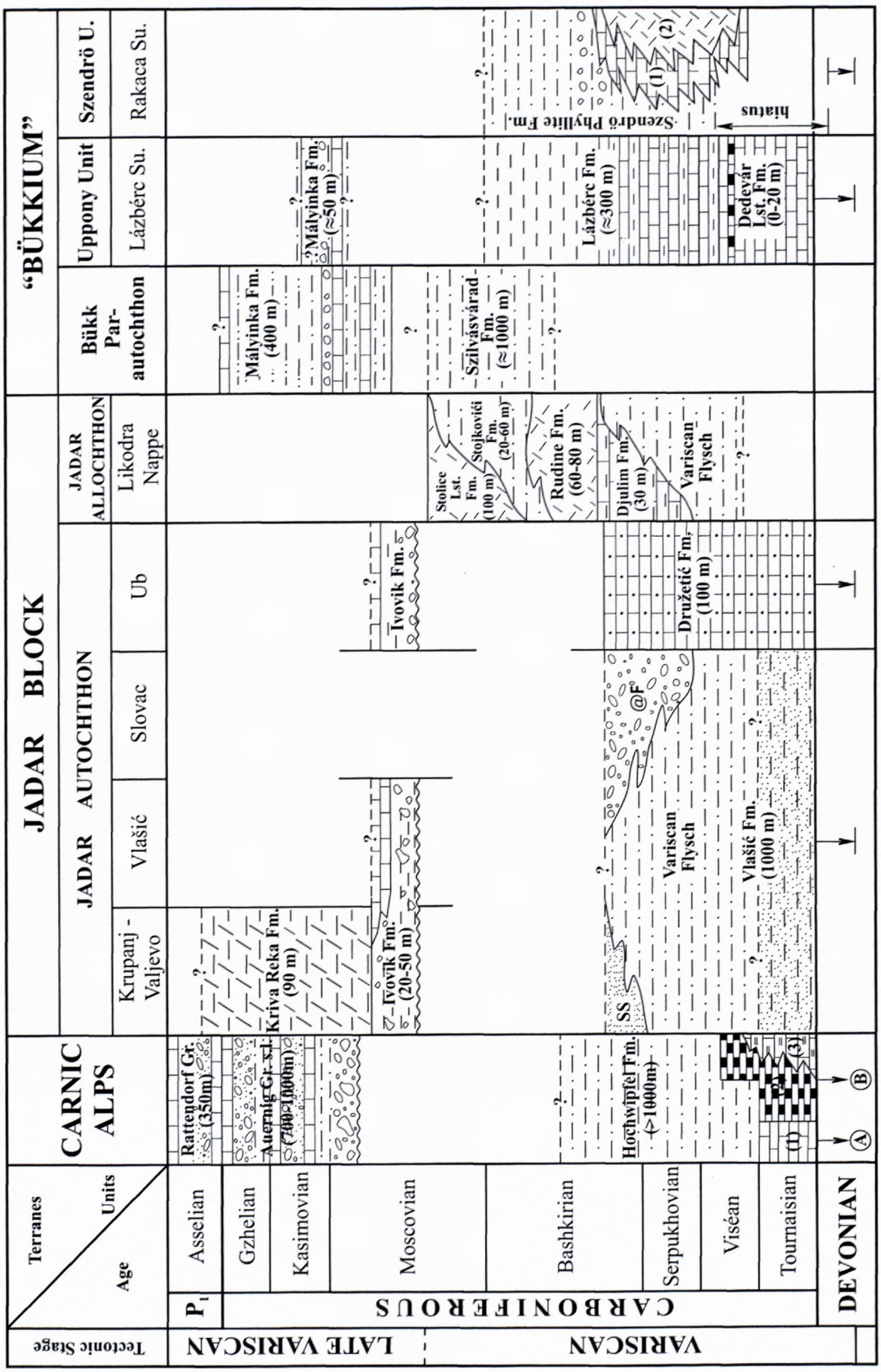

Fig. 2 Correlation of the Variscan (only Carboniferous part) and Late Variscan successions of the Carnic Alps, Jadar Block and „Bükkium" terranes. Abbreviations. Carnic Alps: (A) after Schönlaub, 1985, (1) Kronhof Lst., 10m; (B) after Vai & Venturini, 1995, 1997; Venturini & Spalletta, 1998: (2) lydite, radiolarian chert, shale etc., (Zollner Fm., >100 m), (3) clymenid and goniatitid pelagic limestone. Jadar Block Terrane: SS – Stupnica Sandstone Fm., ŽF – Županjac Fm.; „Bükkium" Terrane (Szendrő Unit, Rakaca Subunit): (1) Verebeshegy Lst. Mb., (2) Rakaca Marble Fm. (s.s).

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Paleozoic rocks of the Jadar area belong to the anchimetamorphic zone, except for those from the southwestern marginal zone, which are metamorphosed in the low-grade part of the greenschist facies (Dobrić et al., 1981).

The „Bükkium" Terrane, in the sense of Kovács et al. (1997), on the basis of formerly prevailing geotectonic concepts, forms the southern section of the NE part of the Pelsonia Composite Terrane. Based on Carboniferous facies relations (Balogh, 1964; Kovács & Péró, 1983, Ebner et al., 1991), it was considered for a while to include the Bükk Parautochthon, Szendrő and Uppony Units. Despite the obvious facies links, however, they show opposite structural vergencies (Csontos, 1988, 1999; Koroknai, PhD thesis in preparation). This fact has received more emphasis in the latest terrane subdivision of Hungary (Kovács et al., 2000). Accordingly, the Bükkia Composite Terrane in the latter sense includes the structurally closely related (Csontos, op. cit.) Bükk Parautochthon, Szarvaskő and Darnó Terranes, whereas the Szendrő and Uppony Units are only tentatively included therein. It should be still mentioned that, among the present authors, P. Pelikán and Gy. Less even doubt the distinct nappe position of the Szarvaskő complex upon the Bükk „Parautochthon" and its distinction from the Darnó Complex. Whereas the Bükk PA and Darnó Units are overstepped by similar Upper Eocene marine formations, the Bükkia, Uppony, Szendrő and adjacent blocks of Pelsonia and Tisia are separated by young Tertiary faults overstepped by Middle Miocene sediments.

3. Lithostratigraphy

In the following review the main lithostratigraphic characteristics of the formations deposited during Variscan and Early Alpine evolution in both investigated terranes are described. The numerous similarities during the Variscan and Early Alpine evolution of the Jadar Block and „Bükkium" terranes confirm their mutual sedimentological and paleogeographic connection.

The Variscan succession began in the Middle Devonian in the Jadar Block Terrane (Filipović et al., 1975), but probably already in the Late Ordovician in the „Bükkium" Terrane (Ebner et al., 1998). Fig. 2 shows only the development of sediments during the Carboniferous and lowermost Permian, with arrows pointing to those formations which continue from the Middle and Upper Devonian (Vlašić and Družetić Fms. in the JBT), as well as to other formations of the same age (Abod Lst. and Uppony Lst. Fms. in the Lázbérc Subunit, Uppony Unit, and Bükkhegy Marble, Abod Lst. and Rakacaszend Marble Fms. in the Rakaca Subunit, Szendrő Unit).

The main characteristics of the Jadar Block Terrane during the Late Paleozoic and Early Mesozoic are the marine development of the Carboniferous and Permian, a continual transition of sedimentation from the Permian to the Triassic, the specific features of Triassic rocks with dolomite of Anisian age, „porphyrite" and pyroclastics of Ladinian age, platform-reefal limestone of Middle and Upper Triassic age and its gradual transition to Liassic limestone. Younger Jurassic formations are not known.

The „Bükkium" Terrane shows the same lithological characteristics up to the end of the Triassic. Lower Jurassic and Lower Middle Jurassic formations are not yet proven. The Upper Triassic platform and basinal carbonates are followed by Bathonian-Callovian variegated radiolarite, then by distal flysch-type sediments of the Eohellenic tectogenesis (Csontos et al., 1991).

3.1. Jadar Block Terrane

In the Jadar Block Terrane three sedimentary successions can be recognized: Variscan, Late Variscan and Early Alpine.

The **Variscan succession** (Middle Devonian – Early Moscovian) in the Jadar Block Terrane, according to the different development of sediments during Variscan evolution, includes the Jadar Autochthon and Jadar Allochthon (Fig. 2).

Jadar Autochthon

During the time of Variscan evolution in the Jadar Trough the clastics of the Vlašić Fm. (the Krupanj-Valjevo, Vlašić and Slovac Units) were deposited, but simultaneously on the Ub intrabasinal rise pelagic limestone of the Družetić Fm. was accumulated (Fig. 2).

The ***Vlašić Formation***, over 1000 m thick, is composed of alternating arenite and siltstone, with rare microconglomerate. There is no paleontological evidence in its lower part; palynomorphs of Upper Devonian and Tournaisian age were found only in the uppermost level. The great thickness of the lower part of the formation is the reason why we also suppose a Middle Devonian age for the Vlašić Fm. The upper part of Vlašić Fm. has characteristics of the ***Variscan*** („Kulm") ***Flysch,*** i.e. rapid vertical change of sandstone and siltstone, various types of lamination, gradation, sedimentary structures, remains of flooded floras of Viséan and Serpukhovian age, and trace fossils (*Phycosiphon, Dyctiodora liebeana* etc.). Only in the thin, cherty limestone intercalations in the Vlašić Fm. near the village of Tekeriš, are found conodont faunas of the uppermost Tournaisian and lowermost Viséan: *Gnathodus typicus, Scaliognathus anchoralis – Doliognathus latus,* and *G. texanus* Zones.

The ***Družetić Formation***, over 100 m thick, is made up of pelagic carbonate rocks of Middle-Upper Devonian and Lower Carboniferous age. In the Devonian parts of the formation numerous conodont zones are defined (Filipović et al., 1975). In the thinner, upper part of the formation (of a thickness of about 15 m), the following Lower Carboniferous conodont zones were identified, viz.: *Siphonodella sulcata, Siph. duplicata, Siph. sandbergi, Sc. anchoralis – Dol. latus, Gnathodus texanus, G. bilineatus bilineatus, Lochreia nodosa, G. bilineatus bollandensis* and *Kladognathus – G. girtyi* group.

At the beginning of the Serpukhovian the Variscan flysch was partially overlain by the ***Stupnica Sandstones*** **(SS)** in the western part of the area, and in eastern part by conglomerate of the ***Županjac Formation*** **(ŽF)**. The regressive tendency of the Serpukhovian ended in the early Bashkirian.

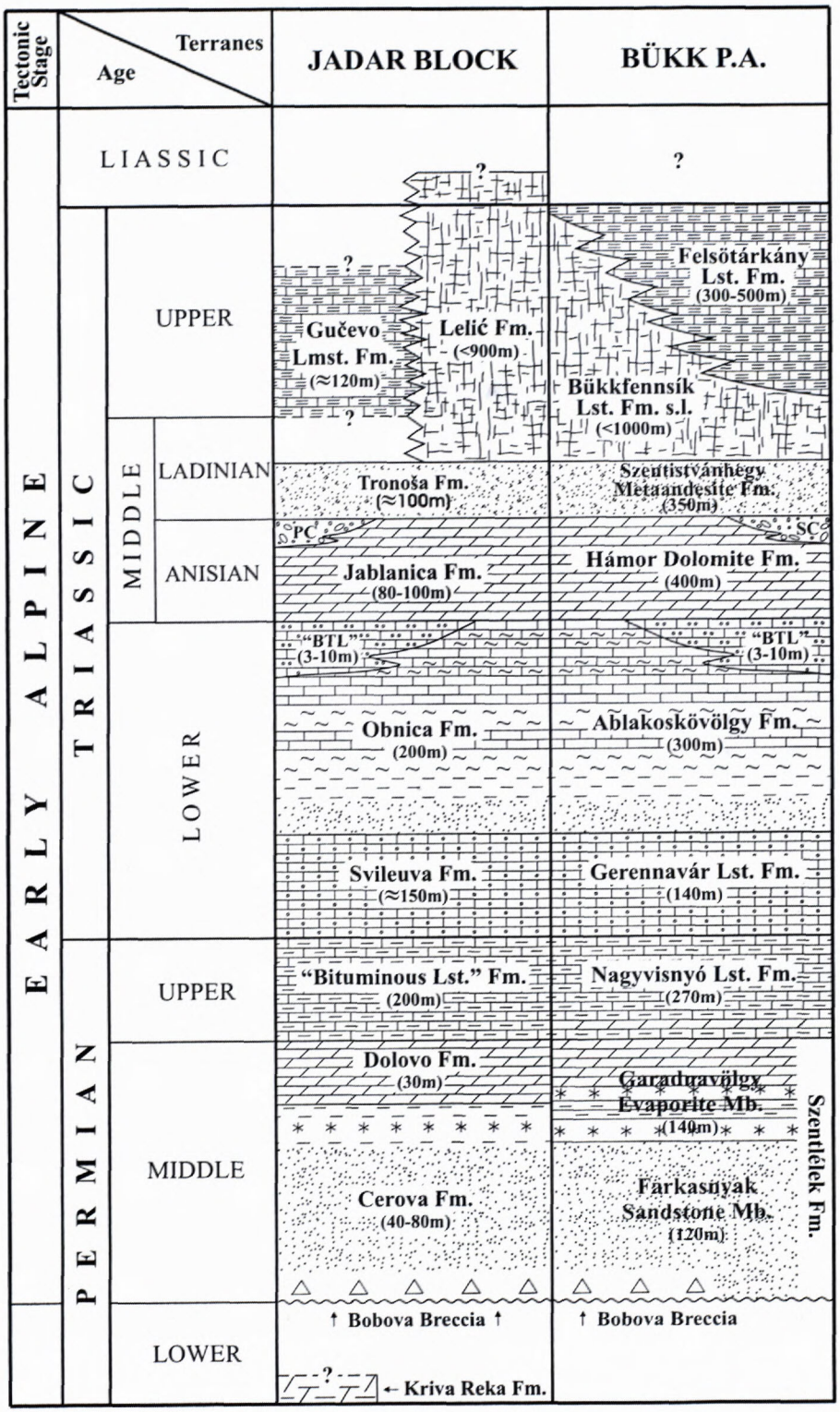

Fig. 3 Correlation of the Early Alpine succession of the Jadar Block and „Bükkium" terranes.
Abbreviations. „BTL" – „Bioturbate Lst." Mb., PC – Podbukovi Conglomerate Mb., SC – Sebesvíz Conglomerate Mb.

Jadar Allochthon

The formations of the Likodra Nappe are quite different from the autochthonous Carboniferous ones (Fig. 2). At the same time they are equivalent to sediments of Carboniferous age of NW Bosnia (Sana-Una Terrane; Protić et al., 2000).

Within the Likodra Nappe the ***Variscan*** („Kulm") ***Flysch*** is overlain in variable thickness (up to 30 m) by the mostly bedded, bluish-gray limestone of the ***Đulim Formation,*** intercalated with marly shale and siltstone. Calcitic, mm-thick veinlets and stylolites within it are typical. The age of this formation is Serpuhkovian-Lower Bashkirian (conodont zones: *Gnathodus bilineatus bollandensis, Declinognathodus noduliferus inaequalis–D. lateralis* and *Idiognathoides corrugatus–Id. sulcatus*).

Above the Đulim Fm., and partly above the Variscan Flysch, lies the ***Rudine Formation***. Its thickness is 60–80 m. It consists of massive, subordinately stratified, gray to dark gray limestone, with frequent foraminifera (Lower Bashkirian, i. e. Severokeltenskian and Prikamskian in

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age), green algae (*Dvinella, Donezella*), brachiopods, corals, etc. At the locality of Rudine a bioherm with *Chaetetes* (probable coralline demosponge) is developed, with abundant solitary corals, pelecypods, crinoids, etc. (Jovanović, 1992).

The ***Stojkovići Formation*** overlies the Rudine Fm. It varies in thickness from 20–60 m and is built up of yellowish or brown siltstone, locally intercalated with shale and sandstone. It contains abundant, but poorly preserved brachiopods and crinoids, rarely bryozoans, bivalves and gastropods of Lower Bashkirian to Vereiskian age.

The youngest rock of the Likodra Allochthon is limestone of the ***Stolice Limestone Formation.*** It is more than 100 m thick, massive or thick-bedded, partially with abundant reef-building organisms. Rare foraminifera (*Archaediscus*) are of Vereiskian/Kashirskian age.

The **Late Variscan succession**, following the Carnic tectogenesis (Vai, 1975), is characterized by molasse development only in the Jadar Autochthon of the Jadar Block Terrane. In the western part of the area mountains were formed, and in other parts molasse depressions. Deposition of molasse began in the Podolskian and ended in the Asselian. At first sediments of the Ivovik Fm. were formed (Krupanj-Valjevo, Vlašić and Ub Units), and later carbonates of the Kriva Reka Fm. (Krupanj-Valjevo Unit).

Olistoliths and clasts of Devonian and Lower Carboniferous limestone in siltstone matrix are characteristic for the older part of the ***Ivovik Formation***. Here synorogenic products of sliding tectonics could be correlated with olistostromes of Prača, Vlasenica (SE Bosnia), Javorje Mt., SW Serbia (Filipović & Jovanović, 1994). The younger part of the formation shows facial changes. In the western part, in near-shore environments, siltstone with brachiopods (*Orthotetes, Neochonetes* and *Choristites* with fine branching costae, etc.) was deposited, intercalated with limestone with fusulinid associations of Podolskian age – *Fusulinella colloniae* Zone (Filipović, 1995). In the other parts of the Jadar Block Terrane (Vlašić and Ub Units) the upper part of this formation is made up of alternations of massive, bedded and thin-bedded silty limestone with woody plant remains.

The ***Kriva Reka Formation*** is developed only in the southern part of the Jadar Block Terrane (Valjevo-Krupanj Unit). It is built of gray, massive or stratified limestone with abundant fusulinids, and sporadically tiny foraminifera, algae, brachiopods, conodonts, pelecypods, bryozoans, crinoids, etc. The presence of stratigraphically important fusulinids and corresponding conodont associations are very characteristic. Four fusulinid associations (zones) were found: the first, of Myachkovskian age with *Fusulinella bocki* and *F. eopulchra*, the second of Kasimovian age with the zone fossils *Protricitites pseudomontiparus* and *Triticitites irregularis* (characteristic in the Russian platform for the uppermost part of the Kasimovian), and the third of Gzhelian age with *Rugosofusulina alpina* and *Quasifusulina longissima* (Filipović, 1995). According to Pantić (1969) in the fourth association of fusulinids consists of *Parafusulina pseudojaponica, P. freganica,* etc., corresponding to the Asselian. The presence of Lower Permian is confirmed by F. Kahler (unpublished data; personal notes given postmortem by courtesy of E. Flügel, 1993), who determined *Cuniculinella* cf. *fusiformis*, *Eosellina* ? sp. and *Pseudoschwagerina* sp., fusulinids characteristic of the Lower Permian.

The **Early Alpine succession** includes formations of the Middle and Upper Permian, Triassic and Lower Jurassic. The development of sedimentation was unique to the entire area of the Jadar Block Terrane and similar to that of the „Bükkium" Terrane (Fig. 3).

In the Permian the similarities are very obvious. They could also be correlated with many areas of the western Paleotethys. In the Jadar Block Terrane sediments of Permian age are represented by three formations: the Cerova Fm., the Dolovo Fm. and the „Bituminous Lst." Fm., the first and second being of Middle Permian, and the third of Upper Permian age.

Due to intensive tectonic events, tectogenetically different basement was formed. Therefore the transgressive sediments of Middle Permian age lie over different formations of the allochthon and autochthon: the Stolice Lst. Fm. in the western part, the Ivovik Fm. in the central part, the Kriva Reka Fm. in the southern part and the Županjac Fm. in the eastern part of the Jadar area.

The ***Cerova Formation***, Middle Permian in age, represented by white and yellow quartz sandstone with rare crinoid detritus, was deposited in a coastal plain environment. The sandstone is medium grained. The main component is angular, undulose quartz.

In the lowest part of this sandstone small lenses of ***Bobova Breccia*** are partially present, which could be correlated with the Tarvis Breccia of the Carnic Alps. Their thickness is of 0.5–3 m, rarely up to 10 m. The breccia consists of angular to medium-rounded fragments of limestone with fusulinids of the Kriva Reka Fm., which means that overthrusting of the Likodra Nappe took place before the Middle Permian.

The sandstone is overlain by purple, greenish and gray-yellowish shale and siltstone, rarely sandstone. Due to the very characteristic color and silky shine (large quantities of mica), these sediments are easily recognizable in the field. This white and yellow sandstone, together with purple and greenish siltstone, is very similar to the Szentélek Formation of the Bükk Mts. (Fülöp, 1994). The presence of gypsum is in connection with the evaporation of salt water in a lagoonal or sabkha environment, under arid conditions, which is characteristic for marine Middle Permian in many areas of the western Paleotethys (Southern Alps, Sana-Una Paleozoic in Bosnia, Nikšićka Župa in Montenegro, Bükk Mts. in Hungary, etc.).

The overlying ***Dolovo Formation*** is made up of thick to thin-bedded, yellow and gray-colored dolomitic limestone, intercalated with marly shale and siltstone. The average thickness is about 30 m. The scarce fossils encountered, *Gymnocodium, Agathammina, Earlandia, Geinitzina,* etc., from dolomitic limestone (dolomicrite, biomicrite, microsparite, etc.) and *Aviculopecten* sp. from

marly intercalations, are not stratigraphic indicators. Therefore, according to the superpositional relationships, the formation is assigned to the Middle Permian in general. Very characteristic for the formation is rauhwacke, which, due to weathering has a net-like, cavernous, i.e. a „boxwork" texture (Leine, 1968). This rauhwacke is monomict and contains a higher content of strontium (965 ppm).

The ***„Bituminous Limestone" Formation*** of Upper Permian age lies over the Dolovo Fm. and passes continually into the overlying Lower Triassic limestone. It consists of limestone, which is gray to black-colored, very fossiliferous (presence of organic matter), bedded (thin-bedded to thick-bedded), rarely massive. In the lower and middle part of the formation intercalations of red and gray sandy shale occur (siliciclastic input).

Macrofauna and microfauna, distributed in a micritic to microsparitic matrix, are very abundant. Calcareous algae, small foraminifera and brachiopods predominate. Simić (1938) was the first to subdivide the Upper Permian, and later Pešić et al. (1988) and Pantić-Prodanović (1994, 1997) separated new horizons. Using all data from the „Bituminous Lst." Fm. the following eight horizons have been established: Horizon 1 with *Edmondia permiana*, Horizon 2 with *Mizzia* (*M. velebitana, M. yabei, M. cornuta*), Horizon 3 with brachiopods: *Tyloplectus, Spinomarginifera, Tschernyschewia, Leptodus,* etc., Bioherm 4 with *Richthofenia*, sponges and bryozoans, Horizon 5 with *Notothyris*, Horizon 6 with *Waagenophyllum indicum*, Horizon 7 with *Conodofusiella, Reichelina* and *Vermiporella*, and Horizon 8 with bellerophons, *Hemigordius* and *Gymnocodium.*

The „Bituminous Limestone" of Upper Permian age passes without interruption in sedimentation into ooidal Lower Triassic limestone (***Svileuva Formation***). As in the entire Tethys area, at the Permian-Triassic boundary living being almost disappeared. No indications of the „boundary clay" have been found as yet, but detailed investigations have not yet been carried out. The Lower Triassic begins with ooidal limestone. Apart from certain horizons of superficial ooids (Pantić-Prodanović, 1987, annual report) in bedded to thickly bedded limestone only rare ostracods and small foraminifera were found, such as *Earlandia tintiniformis* (horizon with ostracods and *E. tintiniformis*; Pantić-Prodanović, 1994).

The sequence continues with the carbonate-terrigenous ***Obnica Formation*** (in the surroundings of the town of Valjevo its thickness is about 200 m). Thin-bedded, yellow and brownish schisty sericitic sandstone, shale, marlstone, sandy and silty, dolomitic limestone, which are in mutual cm-dm alternation, were deposited on a shallow ramp/shelf. In these sediments an abundant mollusk fauna occurs: *Naticella, Turbo, Myophoria, Tirolites,* etc. According to the conodonts, the *Parachirognathodus–Furnishius* and *Neospathodus triangularis–Ns. homeri* Zones of Smithian and Lower Spathian (Budurov & Pantić, 1974, Sudar, 1986) age are determined.

The formation ends with thin-bedded dark gray limestone, rich in bioturbations, parallel laminated and nodular, which becomes massive in the uppermost part (***„Bioturbate Limestone" Mb.***). The limestone is sporadically dolomitic, siltose or clayey, with ooids in some beds.

These rocks pass gradually into gray-colored, brecciated or bedded, very weathered dolomite and dolomitic limestone of Anisian age (***Jablanica Formation***). They are mostly bedded and massive, but in the higher part they are brecciated and crushed. In the locality Podbukovi, as in the Bükk Mts., *Sebesvíz*-type conglomerate is visible, which indicates local uplift (***Podbukovi Conglomerate Mb.***). During the Lower Ladinian in many places in the Jadar Block Terrane, volcanic activity in connection with rift volcanism is manifested by effusions of metaandesite („porphyrite") and its pyroclastics (***Tronoša Formation***). These rocks alternate with thin-bedded, often silicified limestone with nodules and chert intercalations. The „porphyrites" are intensively altered (sericitization, carbonatization, rarely silicification).

In the Upper Triassic different developments occurred. Platform limestone of the ***Lelić Formation*** was gradually developed from the Ladinian, was karstified and transited into reefal, mostly gray, massive and brecciated limestone with megalodonts, corals, hydrozoans, bryozoans, brachiopods, pelecypods and microfauna (*Aulotortus, Endothyra, Trocholina,* etc.). Laterally the ***Gučevo Limestone Formation*** was deposited in basinal environments of the deep borderland or slope. This limestone is gray, thin to thick-bedded, with chert nodules, abundant in radiolarians, „filaments" and conodonts of Carnian and Norian age (*Paragondolella foliata, Pg. polygnathiformis, Pg. nodosa, Metapolygnathus abneptis,* and *Epigondolella postera* zones; Sudar, 1986).

The Upper Triassic rocks of the Lelić Fm. pass gradually into Liassic limestone. They are red and gray-colored, thick-bedded, of a thickness up to 10 m. In this limestone foraminifera of Lower Jurassic age were found: *Involutina liassica* and *Vidalina martana.*

3.2. „Bükkium" Terrane

3.2.1. Bükk Parautochthon Unit

Variscan succession. Late Paleozoic formations occur at surface only in the northern part of the mountains, in the so-called „North Bükk Anticline" of the Bükk Parautochthon Unit (hereafter Bükk PA) (Balogh, 1964; Fülöp, 1994). Only the end-member of the Variscan cycle is known, the flysch-like, distal turbiditic ***Szilvásvárad Formation***, consisting of an alternation of dark gray to black shale, siltstone and sandstone. It occurs in the core of the anticline with an estimated thickness exceeding 1000 m. Underlying formations are not known; it is overlain on the two limbs of the anticline by the marine molasse-type Mályinka Fm. In the absence of fossils, and based on the latter, its age is pre-Podolskian, probably higher Bashkirian and early part of Moscovian. An unconformity between the two formations could not yet be proven. In terms of its sedimentological character the Szilvásvárad Fm. can be compared with the distal turbiditic middle and upper members of the Szendrő Phyllite Fm., which are of post-Early Bashkirian age.

Fig. 4 Bobova Breccia at the base of the whitish sandstone of the Farkasnyak Sandstone Mb. of Szentlélek Fm., Middle Permian. Borehole Mályinka-13, (37,4-38,7 m), Csikorgó, NE Bükk Mts.

The **Late Variscan succession** is represented only by the marine molasse-type ***Mályinka Formation*** of 400 m thickness. It consists of fossiliferous shale, sandstone (mainly with brachiopods and crinoids), with three bluish-gray limestone horizons rich in calcareous algae, fusulinids and other fossils, each being 10 to 50 m thick. The age of the lower two is Late Moscovian (Myachkovskian; Berenás Member in Fülöp, 1994), as indicated by fusulinids: *Fusulinella* ex gr. *bocki, Fusulina* ex gr. *elegans, Pseudoendothyra pseudosphaeroidea,* etc. However, from the lowermost part of the formation *Hemifusulina moelleri* was reported from some limestone intercalations (Rozovskaya, 1963), pointing to a Podolskian age. The age of the third, uppermost limestone horizon (Csikorgó Member in Fülöp, 1994) is Gzhelian according to its fusulinds (*Quasifusulina longissima, Qu.* cf. *tenuissima, Qu. elongata; „Pseudofusulina" pseudojaponica,* etc.). Nevertheless, a partly Asselian age cannot be quite excluded; however, sure evidence is missing so far (Kozur, 1984).

In the Early Permian the region of the Bükk PA unit was uplifted and underwent erosion, which for the most part removed the higher (Kasimovian-Gzhelian) portions of the formation. Equivalents of the Rattendorf and Trogkofel Groups of the Carnic Alps are missing here, as well as in the Jadar Block Terrane.

The **Early Alpine succession** includes formations of Middle Permian to Upper Jurassic age, but there is no evidence for Lower and lower Middle Jurassic ones in this unit so far. The ***Szentlélek Formation*** disconformably overlies different levels (Moscovian to Gzhelian) of the Mályinka Fm. It begins with white, whitish gray to greenish quartz sandstone, then follows with red or reddish-brown sandstone and siltstone, representing a coastal plain environment (***Farkasnyak Sandstone Mb.***, of 100–130 m thickness). In its basal part a limestone breccia horizon occurs, equivalent to the *Bobova Breccia* of the Jadar Block Terrane (Fig. 4). The 120–150 m-thick ***Garadnavölgy Evaporite Mb.*** represents sabkha conditions and is built up by an alternation of purple or green siltstone-mudstone, subordinately sandstone, white gypsum and, in lesser amount, anhydrite, as well as gray dolomite. The formation, being in an underlying position to the Nagyvisnyó Lst. Fm., is regarded as of „Middle Permian" age in general, without age indicator fossils.

The ***Nagyvisnyó Limestone Formation*** (Bellerophon Fm. in the classical Alpine literature) of 270 m thickness develops with continuous transition from the Szentlélek Fm. The boundary is defined where the purple-green siltstone, resp. gypsum-anhydrite intercalations disappear from among the dolomite beds. The lower 30 m of the formation is dominated by dolomite, whereas the remaining part is formed by usually 20–30 cm thick, very fossiliferous (calcareous algae: *Mizzia velebitana, Vermiporella serbica, Gymnocodium bellerophontis,* etc., brachiopods: *Leptodus nobilis, Tschernyschewia, Tyloplecta,* etc.) black or dark gray limestone beds with 2–10 cm-thick, black, marly-silty intercalations. Ostracods (Kozur, 1985) and small foraminifera (Bérczi-Makk, 1992; Bérczi-Makk et al., 1995) are also very common. Small coral buildups with *Waagenophyllum indicum* are characteristic for the middle part of the formation, whereas the calcareous sponge *Peronidella baloghi* occurs in its upper part in the horizon with *Leptodus nobilis.* A faunal correlation with the Jadar Block Terrane and the other areas of the Dinarides was presented earlier by Pešić et al., 1988.

In the Bükk Mts. the ***„boundary clay"*** event at the Permian/Triassic boundary can be recognized in a few sections. The lowermost Triassic is represented by the light-colored, ooidal ***Gerennavár Limestone Formation*** of 120 m (or even more) thickness. At the formation boundary the very rich Permian fossil association disappears and only a few Permian small foraminifera and the calcareous algae *Gymnocodium* are still present just above it, followed by a thin horizon with the foraminifer *Earlandia tintinniformis*, which occurs somewhat higher (Bérczi-Makk, 1987).

The ***Ablakoskővölgy Formation*** of 300 m thickness, with four members, represents mixed carbonate-terrigenous sedimentation on a ramp environment. Its lower part consists of greenish-purplish sandstone and siltstone, with sandy-marly limestone intercalations, and higher up

gray, bedded or platy limestone alternating with marl-shale horizons, containing *Naticella, Turbo, Tirolites*, etc. The uppermost member, not present in all sections, is formed of bioturbated limestone. The light colored, locally dark gray, peritidal ***Hámor Dolomite Formation*** of 300 m thickness seems to represent the entire Anisian. Locally in its top part emersional conglomerate, the ***Sebesvíz Conglomerate Mb.***, occurs (for details see Velledits, 1999).

The Lower Ladinian ***Szentistvánhegy Metaandesite („Porphyrite") Formation*** of 200–300 m thickness is composed of greenish or purplish lava and pyroclastics. Acidic (dacite, rhyolite) and slightly more basic (basalto-andesite) varieties also occur.

After this volcanic event, due to extensional movements, platform and basinal environments were differentiated. Platform carbonates are grouped herein together in Fig. 3 as the ***Bükkfennsík Limestone Formation***, which is the most widespread metamorphosed variety. Its age can be considered, based on the relationships with the conodont-dated basinal formations, as Late Ladinian to Norian/Rhaetian (Velledits, 2000). Rich Carnian reef biotas were published from non-metamorphosed varieties from several places (Velledits & Péró, 1987; Flügel et al., 1991/92) and a relatively poor Norian to Rhaetian one from one locality (Riedel et al., 1988). Gray, cherty limestone of basinal and partly slope facies is grouped together as the ***Felsőtárkány Limestone Formation***. Conodonts indicate its age from the Ladinian/Carnian boundary (*Metapolygnathus mungoensis, M. diebeli*) up to the Rhaetian (*Neospathodus posthernsteini*) (Kovács, in Velledits, 2000). In the underlier of the cherty limestone or at its base a second volcanic horizon occurs with intra-plate type basalts (Szoldán, 1990). Some partly siliciclastic formations (Vesszős Fm., Várhegy Fm.) of problematic age and of local occurrence, not recognized in the Jadar Block Terrane up to now, are not discussed herein.

3.2.2. Uppony Unit – Lázbérc Subunit

Variscan succession. The Upper Devonian pelagic, tuffitic Abod Lst. Fm. is followed by the very condensed (max. 10–20 m), similarly pelagic ***Dedevár Limestone Formation*** of flaser type, lacking tuffitic influence, but with a characteristic carbonatic lydite horizon in the Lower Viséan, indicated by *Gnathodus delicatus*. This formation is known only in a few outcrops. The ***Lázbérc Formation*** of much larger surface occurrence is built up by bluish-gray to dark bluish-gray basinal limestone, intercalated with dark shale, with conodonts from the Late Viséan *Paragnathodus nodosus* to the Early Bashkirian *Idiognathoides sinuatus* Zones. A thick (100–200 m) zone of shale and marly shale may be even younger than Lower Bashkirian. The entire formation, the thickness of which can be estimated at 300–400 m, lacks features of resedimentation, e.g. it is not a flysch-type sediment.

Late Variscan succession. The molasse stage can be represented by a zone of sandy limestone, sandstone, and pebbly sandstone, occurring in a narrow zone within the Lázbérc Fm. at the southern margin of the subunit. As the pebbly sandstone already contains small (up to 1–2 cm diameter), rounded white quartz and black lydite, it can be considered as a postorogenic sediment. It is tentatively referred to the ***Mályinka Fm.*** of the Bükk Parautochthon Unit by Kovács (1992), whereas Fülöp (1994) distinguishes it as the Derennek Mb. of the Lázbérc Fm.

3.2.3. Szendrő Unit –Rakaca Subunit

Variscan succession. Carboniferous pre-flysch sediments are fully developed beginning with the Lower Viséan in the southern subzone of the northern marble zone of the Szendrő Hills (Kovács, 1992, and in Ebner et al., 1991, 1998), whereas the Variscan flysch forms the middle, phyllite zone of the hills (Péró, in Fülöp, 1994).

The bluish-gray to white-banded ***Rakaca Marble Formation*** of about 200 m thickness in the locality of Kopaszhegy begins with an alternation of marble beds and brownish gray crinoidal limestone, the latter containing conodonts of the Early Viséan *Gnathodus texanus* Zone. This part represents a platform slope setting. In other sections the marble of platform facies is underlain, interfingering and overlain by the ***Verebeshegy Limestone Mb.*** of basinal facies. Its oldest part underlying the platform facies contains conodonts of the Late Viséan *Paragnathodus nodosus* Zone, whereas the youngest one on top of the platform those of the Early Bashkirian *Idiognathoides sinuatus* Zone. The zones in between are also represented in the basinal facies, laterally interfingering with the platform facies.

The ***Szendrő Phyllite Formation*** of about 600 m thickness represents the Variscan flysch stage and lies for the most part over the Verebeshegy Lst. Mb.-Rakaca Marble Fm. In its lower, olistostromal Meszes Member it already contains the clasts of the Early Bashkirian *Idiognathoides sinuatus* Zone. However, in the clast material of the olistostromes all ages down to the Middle Devonian are present. As opposed to this proximal type lower member, the middle and upper members of the formation are of distal flysch type.

4. Conclusions

The comparison of Late Variscan and Early Alpine succession of the presently distantly separated Jadar Block and „Bükkium" terranes revealed many more similarities than they show with the terranes presently surrounding them. An additional comparison with the classical Carboniferous-Permian succession of the Carnic Alps (Fig. 5) revealed their close paleogeographic affinities within the western Paleotethyan domain. In analyzing the successions the following main conclusions can be drawn:

1. During the Variscan synorogenic and postorogenic evolution, all the three compared units belonged to the southern European Variscan foreland, e. g. to the Noric-Bosnian Zone according to Flügel, 1990, and Neubauer & von Raumer, 1993, or Carnic-Dinaridic Block, according to Vai, 1995, 1998. All of them were parts the flysch basin (although with different age constraints) formed in

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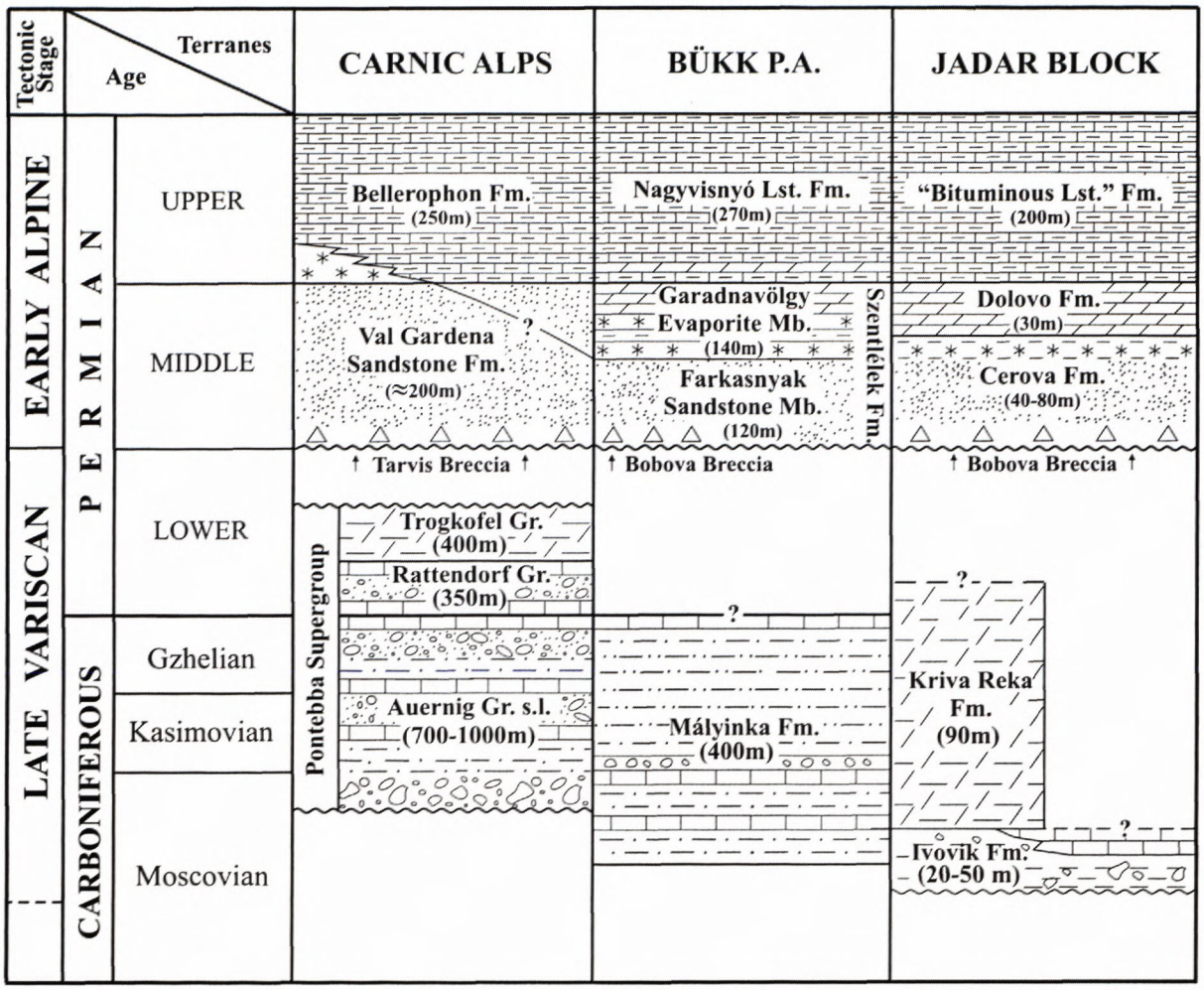

Fig. 5 Correlation of the Late Variscan – Early Alpine (upper Middle Carboniferous – Upper Permian) successions of the Carnic Alps (after Vai & Venturini, 1995; Venturini & Spalletta, 1998), „Bükkium" and Jadar Block terranes.

front of the advancing Variscan nappe system (Neubauer & von Raumer, 1993, Vozárová, 1998). This area was characterized by mostly marine Late Variscan and earliest Alpine (Late Carboniferous-Permian to the passage to the Triassic) development.

2. Whereas in the Jadar Allochthon the Variscan flysch deposition mostly preceded basinal and shallow marine carbonate sedimentation, or was partly contemporaneous with it (interfingering with the Đulim Fm.), in the Szendrő Unit it mostly succeeded the basinal and shallow marine carbonate deposition, or was partly contemporaneous with that (interfingering with the Verebeshegy Lst. Mb.). It is important to note that basinal carbonate deposition in all of the Jadar Allochthon, Szendrő and Uppony Units persisted until the Early Bashkirian *Idiognathoides sinuatus* Zone, represented by similar lithologies (bluish gray to dark bluish gray limestone of the Đulim Fm., Lázbérc Fm. and Verebeshegy Lst. Mb., correlatable also with the Dult Fm. of the Graz Paleozoic; Ebner et al., 1991, 1998), whereas in the Carnic Alps it came to end at the Tournaisian/Viséan boundary.

Although the shallow marine Rudine Fm. postdates the Variscan flysch sedimentation in the Jadar Allochthon, and the Rakaca Marble Fm. predates most of that in the Szendrő Unit, it may be a non-metamorphosed facial equivalent of the latter. The presence of a Carboniferous fossil-proven biohermal facies in one of the compared units is therefore important, as the Rakaca Marble has no in situ equivalents in the Carboniferous of the Carnic Alps and Graz Paleozoic, but occurs only in the form of clasts (Ebner et al., 1991, 1998).

3. As opposed to the S-vergent thrusting and folding during the Carnic phase in the Carnic Alps (Vai, 1975, 1998; Castellarin & Vai, 1981), no evidence for such a tectonic and corresponding metamorphic event could be proven in the compared Jadar Block and „Bükkium" terranes, e.g. between the Ivovik and Kriva Reka resp. Szilvásvárad and Mályinka Formations. Evidence for Variscan metamorphism is lacking in the „Bükkium" (Árkai, 1983).

4. The Auernig Group of the Carnic Alps represents the most nearshore depositional setting, with abundant quartz-conglomerate levels, whereas the Kriva Reka Fm. of the Jadar Block Terrane is in the most offshore setting with its 90 m-thick fusulinid limestone lacking siliciclastics. The up to 400 m shale-sandstone-limestone succession of the Mályinka Fm. of the Bükk PA Unit

represents a transitional setting between the two, also containing some quartz conglomerate.

5. A Variscan unconformity between the Kriva Reka Fm. and Middle Permian clastics (Cerova Fm.) can be clearly proven in the Jadar Block Terrane. In the Bükk PA Unit at least a disconformity can be proven, with the Szentlélek Fm. resting on different levels of the Mályinka Fm., indicating post-Carboniferous uplift and erosion. Equivalents of the 800 m-thick succession of the Rattendorf and Trogkofel Groups of the Carnic Alps are missing in both units.

6. The Middle Permian Neotethyan transgression, both in Jadar Block and „Bükkium" terranes began with whitish sandstone of a coastal plain environment. Limestone breccia (Bobova Breccia) at the basal part of these successions can be correlated with the Tarvis Breccia of the Carnic Alps. Following this transgression the two terranes showed a practically identical development until the end of the Triassic/beginning of the Jurassic. The main characteristics of this evolution are:

– Marine Late Permian deposition ("Bellerophon Fm." in general) with transition into the marine Early Triassic one (with the „boundary clay event" at the Permian/Triassic boundary, proven so far only in the Bükk PA Unit);

– Anisian carbonate ramp environment with peritidal dolomite, followed by partial uplifts of some blocks, indicated by Sebesvíz-type conglomerate;

– Early Ladinian andesite volcanism, succeeded by differentiation of carbonate platform and basin environments;

– From the earliest Jurassic onward (after the deposition of some cherty limestone), there is no sedimentological record for correlation.

7. The original place of the two terranes could have been at the Dinaridic/Adriatic margin of Neotethys, probably near to the Sana-Una Terrane, which is today in NW Bosnia (Protić et al., 2000). From this position the Jadar Block was displaced in the Late Cretaceous (Karamata et al., 1994), and the „Bükkium" Terrane in the course of the (Late Cretaceous-) Tertiary transpressional movements between the ALCAPA and Tisia Terranes (Csontos & Nagymarosy, 1998; Haas et al., 2000).

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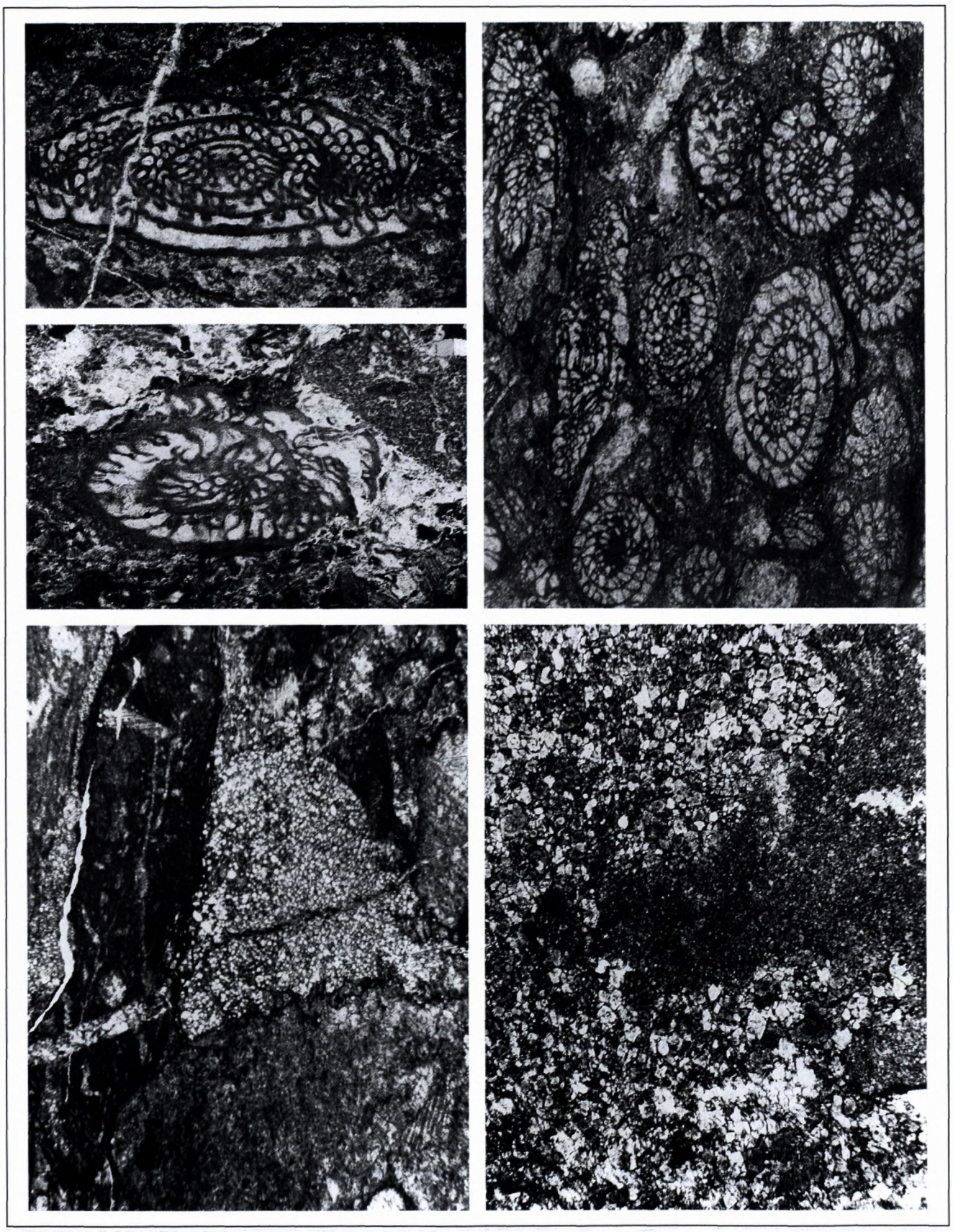

Plate I

Figs. 1–2 Biomicrosparite with fusulinids. Kriva Reka Fm., Upper Moscovian – Asselian. Kriva Reka Sklop near to Krupanj, NW Serbia. sample 116, N II, x 12.

Fig. 3 Fusulinid biomicrosparite, Mályinka Fm., Csikorgó Mb. Gzhelian (to Asselian?). Type section at Csikorgó, NE Bükk Mts., NE Hungary. N II, x25.

Fig. 4 Bobova Breccia, lowermost part of Cerova Fm., Middle Permian. Bobova, NW Serbia, sample 7381, N II, x30.

Fig. 5 Bobova Breccia with strongly recrystallized matrix. Middle Permian. Borehole Mályinka-13, (35,7 m), Csikorgó, NE Bükk Mts. N II, x12,5.

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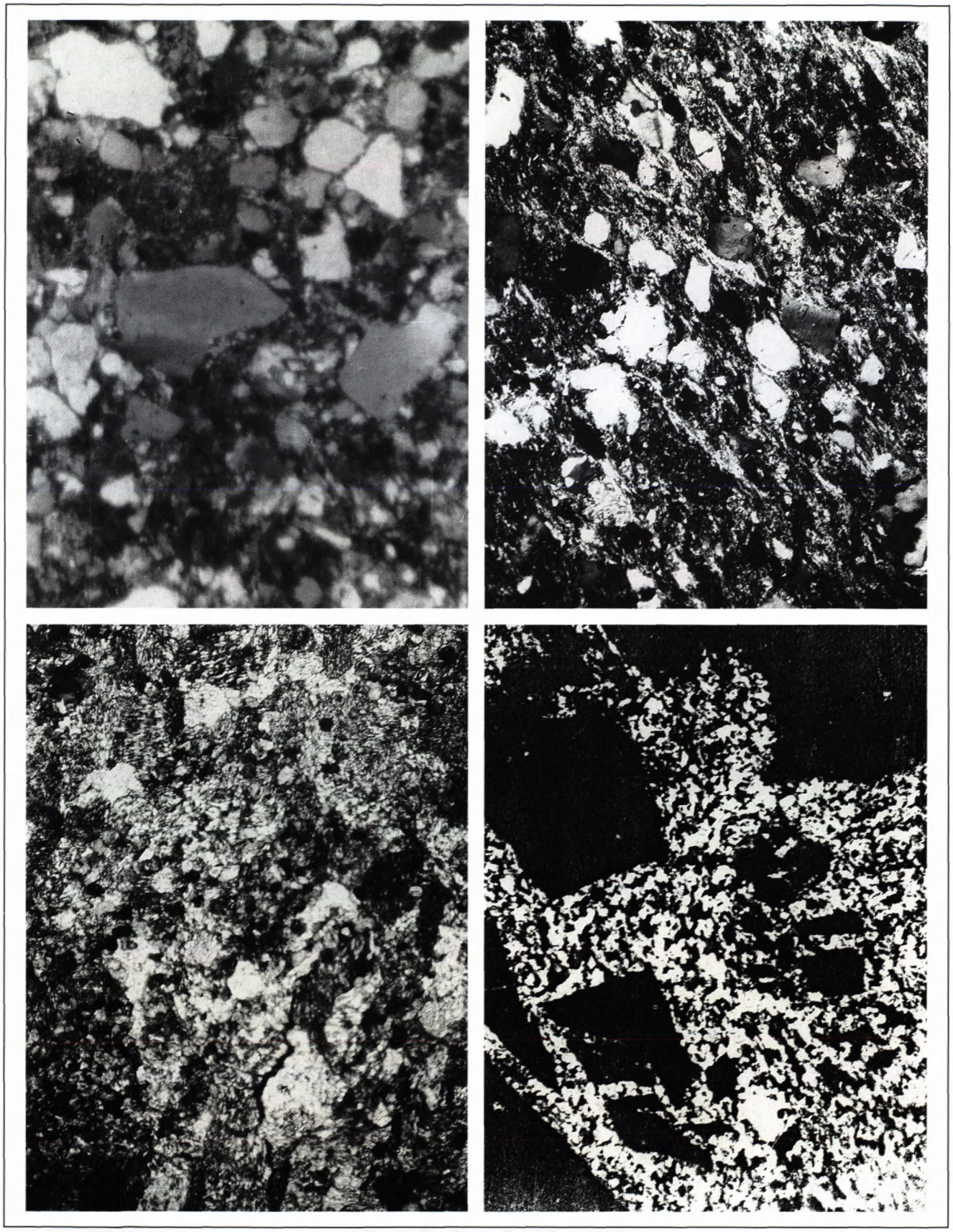

Plate II

Fig. 1 Whitish sandstone, Cerova Fm., Middle Permian. Obradovići, NW Serbia, sample 7225, N X, x30.

Fig. 2 Whitish sandstone, Szentlélek Fm., Farkasnyak Sandstone Mb., Middle Permian. Borehole Mályinka-13, (13,5 m), Csikorgó, NE Bükk Mts., N X, x30.

Fig. 3 Gypsum, Cerova Fm., Middle Permian. Sample from borehole on road Mojković -Bela Crkva, (20-80 m), NW Serbia, N II, x30.

Fig. 4 Gypsum (light) and dolomite (dark), Szentlélek Fm., Garadnavölgy Evaporite Mb., Middle Permian. Borehole Nagyvisnyó-21, (160,0 m), N X, x25

Plate III

Fig. 1 Rakaca Marble Fm., Kopaszhegy Mb.: epimetamorphosed platform-slope facies of Viséan age. Thick, light beds represent redeposited platform material, whereas brownish, thin bedded horizons are crinoidal limestone of slope facies. Rakacaszend, Kopaszhegy quarry, Szendrő Hills, NE Hungary.

Fig. 2 Bioclastic limestone, platform facies, with Chaetetes sp., bellerophons, brachiopods, etc. Rudine Fm, Bashkirian, Middle Carboniferous. Rudine near Krupanj, NW Serbia.

Fig. 3 Bobova Breccia at the basal part of the Cerova Fm. Middle Permian. Cerovaćka glavica near to Krupanj, NW Serbia.

Fig. 4 Whitish sandstone, Cerova Fm., Middle Permian. Road Stolice – Cerova, NW Serbia.

Plate IV

Fig. 1 Whitish sandstone, Farkasnyak Sandstone Mb., Szentlélek Fm., Middle Permian. Borehole Mályinka-13, (≈12-21 m), Csikorgó, NE Bükk Mts.

Fig. 2 Alternation of green and purple argillite with gypsum. Garadnavölgy Evaporite Mb. of Szentlélek Fm., Middle Permian. Borehole Nagyvisnyó-18, (205,9–209,8 m).

Fig. 3 Gypsum alternating with black argillite and gray dolomite. Garadnavölgy Evaporite Mb. of Szentlélek Fm., Middle Permian. Borehole Nagyvisnyó-13, (≈ 220 m).

Fig. 4 Nagyvisnyó Lst. Fm., Upper Permian. Type section in Mihalovits quarry, Nagyvisnyó, northern foreland of Bükk Mts., NE Hungary.

Plate V

Fig. 1 Rauhwacke in the Dolovo Fm., Middle Permian. Mojković, NW Serbia.

Fig. 2 Organodetritic limestone, „Bituminous Lst." Fm., Upper Permian. Obnica river valley, NW Serbia. Horizon 7 with Codonofusiella, Reichelina and Vermiporella; Horizon 8 with bellerophons, Hemigordius, Permocalculus, Gymnocodium; Horizon 3 with brachiopods: Leptodus, Tschernyschewia, Tyloplectus, Spinomarginifera, etc.

Fig. 3 Podbukovi Conglomerate Mb. in the uppermost part of the Jablanica Fm., Upper Anisian, Middle Triassic. Road Valjevo-Kosjerić, NW Serbia.

Fig. 4 Sebesvíz Conglomerate Mb. in the uppermost part of the Hámor Dolomite Fm. and below Szentistvánhegy Metaandesite Fm. (overturned position), Upper Anisian, Middle Triassic. Forestry road, Sebesvíz Valley, NE Bükk Mts., NE Hungary.

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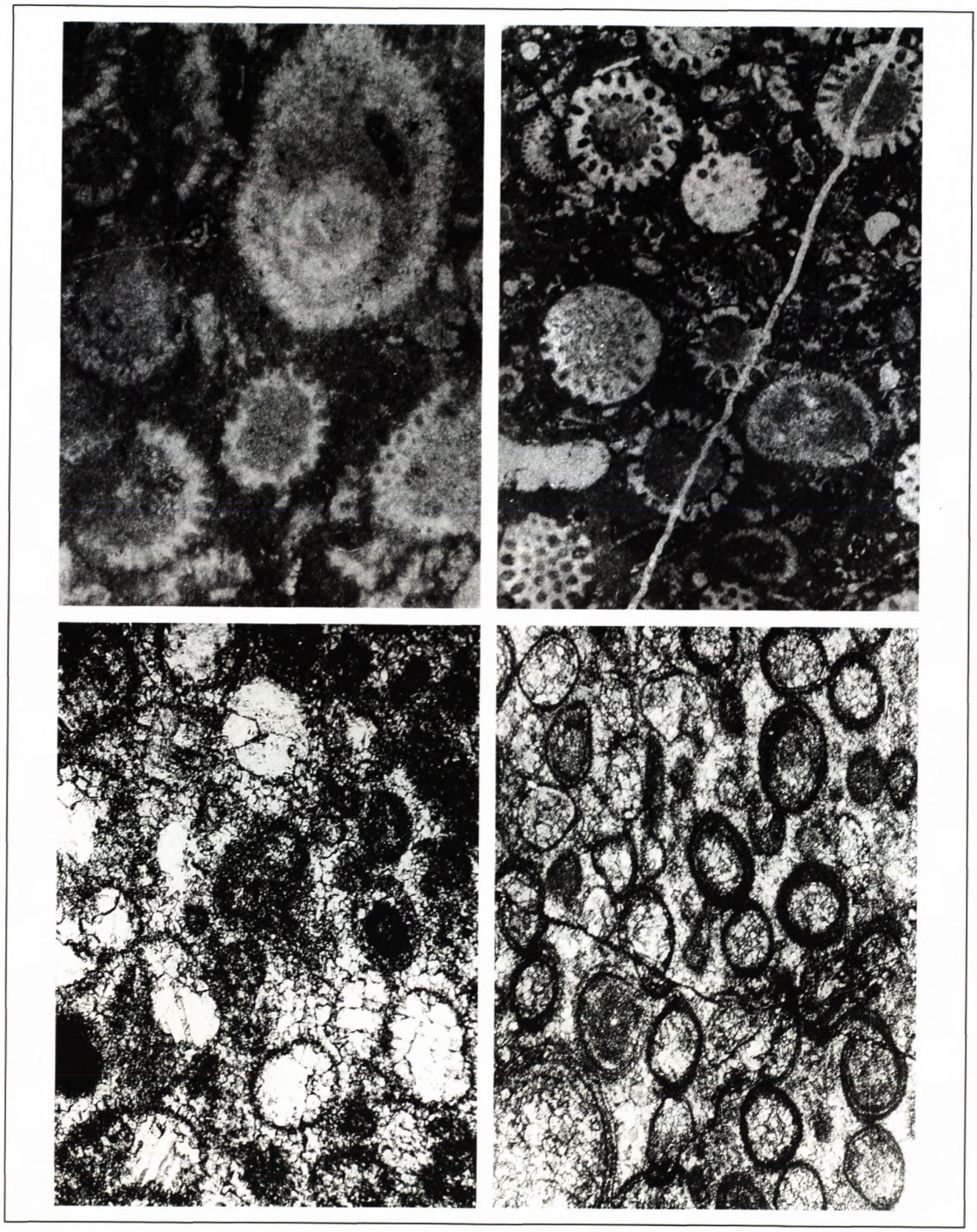

Plate VI

Fig. 1 Dolomitic biomicrosparite with dasycladacean algae (mainly Mizzia sp.). „Bituminous Lst." Fm., Upper Permian. Zeljići, NW Serbia, sample 962, N II, x17,5.

Fig. 2 Biomicrosparite with dasycladacean algae (mainly Mizzia sp.). Nagyvisnyó Lst. Fm., Upper Permian. Máloldal, W of Mihalovits quarry, Nagyvisnyó, NE Hungary, N II, x25.

Fig. 3 Oosparite. Svileuva Fm., lowermost Triassic. Svileuva-Lipovac, NW Serbia, sample from borehole Sv-3, (80 m), N II, x30.

Fig. 4 Oosparite. Gerennavár Lst. Fm., lowermost Triassic. Type section at Gerennavár, NE Hungary, sample G-2/1, N II, x25.